Multimodal learning analytics on sustained attention by measuring ambient noise

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Abstract

In this research, a learner's sustained attention in the remote learning context will be studied by collecting data from different sensors. By combining the results of these sensors in a multi-modal analytics tool, the estimation of the learner's sustained attention can hopefully be improved. This research will mainly focus on microphone recordings of ambient sound in a learners room. The main research question of this research was "How can ambient noise sensing aid in a multi-modal analytics tool to track sustained attention?". The multi-modal learning analytics tool, if accurate enough, could potentially be used by teachers to make their material more engaging and could help learner's to keep their focus while performing a learning task (Schneider et al., 2015). The research resulted in a model with 61% accuracy. This percentage needs to be further researched, since because of the COVID situation, not enough data could be collected to train the model. Because of the relatively low accuracy of the model, it was found that ambient noise sensing can aid the multi-modal analytics tool to some extent by adding some data-points it is certain about, when the mobile movement tracking model does not detect a distraction. If the model improves in future research, the model could be able to help mobile movement tracking model, even if the mobile movement tracking model already predicts a distraction with bigger then 50% certainty.

1 Introduction

In this research, a learner's sustained attention in the remote learning context was studied by collecting data from different sensors. It will be researched if a model can be constructed to predict if a learner is distracted using the various sensors and these models will be combined to try to improve the models accuracy in a multi-modal model. This research mainly focused on microphone recordings of ambient sound in a learners environment. The multi-modal learning analytics tool, if accurate enough, could potentially be used by teachers to make their material easier to learn and could help learner's to keep their focus while performing a learning task (Schneider et al., 2015). In the current world where remote teaching is necessary, this research becomes more important as it is easier to see if someone is distracted by seeing him/her before you in the class rather then behind a webcam.

The main research question of this research was "How can ambient noise sensing aid in a multi-modal analytics tool to track sustained attention?". This main question was split into 5 different sub-questions to help answer the main research question. It was expected that by combining multiple sensors, a more accurate model could be achieved when compared to uni-modal models relying on a single sensor. Research on people being distracted by sound had already been done before (Ke et al., 2021; Lee, 2019; Morgan, 1917) and it was already known that people can get distracted by sound containing fluctuating frequencies. The interesting part of this research was to find out if a model could be created that automatically detects ambient sound and predicts if this sound is distracting.

The research could focus on two different types of sound: vocal and non-vocal sounds. Because of the cocktail effect (Bronkhorst, 1999) it became hard to focus this research on vocal sounds. Vocal sounds are very subjective, someone will not immediately react to someones else's name, but will notice his/her name for example. Therefore this research focused on non-vocal sounds. Multiple different sounds where used during the experiment, some sounds like machine noise and music that can occur in a (at home) learning environment, some sounds that should be relaxing and should help the learner focus and some sounds consisting of fluctuating frequencies.

The research resulted in a model with 61% accuracy. The model seemed promising, though it needs to be further researched. Because of the COVID situation, not enough data could be collected to train the model. Unfortunately, in the end , two of the 3 other researchers where not able to provide a working model due to various reasons. Therefore the multi-modal model was only created with the ambient noise tracking model and the mobile movement tracking model (Deininger, 2021). Because of the relatively low accuracy of the model, it was found that ambient noise sensing can aid the multi-modal analytics tool to some extent by adding some data-points it is certain about, when the mobile movement detection model does not detect a distraction. If the model improves in future research, the model could be able to help phone movement detection model, even if it already predicts a distraction with bigger then 50% certainty.

2 Background

In this research, a learner's sustained attention in the remote learning context was studied by collecting data from different sensors. By combining the results of these sensors in a multi-modal analytics tool, it was tried to improve the estimation of the learner's sustained attention. By studying the sustained attention of a learner, teachers can improve there study material and adapt their lectures, thereby improving the amount of material a learner learns. A multi-modal learning analytics tool, if accurate enough, can also be used by learners to stay focused while performing a learning task (Schneider et al., 2015).

The research of this system was done by 4 different students, all focusing on different sensors and its data (Deininger, 2021, Toonder, 2021, van der Voort, 2021). In this specific research, the main focus was on measuring ambient noise and finding a correlation between learner's losing focus and data from microphones recording ambient noise in the room the learner is situated in.

Research to people being distracted by noise had already been done before and it had shown that people can be distracted by noise and that this distraction can be measured (Ke et al., 2021; Lee, 2019; Morgan, 1917). The interesting part about this study is to see if distracting sounds can be recorded by a microphone and if using this data it can be predicted if this sound is a distracting noise to help the multi-modal system to detect a distraction and its source.

2.1 Main research question: How can ambient noise sensing aid in a multi-modal analytics tool to track sustained attention?

The main goal of this research was to find out if ambient noise sensing can aid a multi-modal analytics tool to track sustained attention. This multi-modal learning tool consists of the combined model created by the four separate researches. It was expected that ambient noise sensing can aid in finding possible distractions by measuring noises that will distract nearly everyone, however that it will not be possible to exclusively use noise measurements to detect a distraction. This is due to the huge variety of different sounds that can be measured and the different reaction people can have to these sounds (Lee, 2019; Min et al., 2016). This sensing will probably help the multi-modal analytics tool by confirming a possible distraction, detected by one of the other models.

The main research question was divided into 5 different sub-questions that where answered during this research to work towards an answer for the main research question. The 5 sub-question are:

1. What should be measured on the noise (dB, Hz, Hz fluctuation or categorized sounds?)
2. Should background noise be filtered to reliably determine if a noise is distracting?
3. If the background noise needs to be filtered, how can this be filtered without losing possible noises that distract a learner?
4. Can a correlation between noise variation and distraction reliably be found in the microphone recordings?
5. How does the correlation between noise variation and distraction help the multi-modal analytic tool to track sustained attention?

The sub-question will be further described in section 3.

3 Methodology

To answer the main research question, first the 5 sub questions had to be answered. This was either done with a literature study, user test or by testing possible solutions. In this section the methodology to obtain answers will be described in the order in which the sub questions will be answered.

3.1 Sub-question: What should be measured on the noise (dB, Hz, Hz fluctuation or categorized sounds)?

To know what metrics needed to be measured in the user study, it needed to be found what makes noise distracting and how this can be measured. To find this answer, a literature study was conducted. To find literature on this topic, the following search query was used: (auditory OR (ambient AND noise) OR noise OR sound) AND (attention OR distraction OR (sustained AND attention)). The main search engine used for this research was the TU Delft online library. Articles where only included if the research was conducted on non-speech sounds, no other inclusion and/or exclusion criteria where applied.

During this literature study it was found that the distracting factor of sound is frequency fluctuation (Perham et al., 2007). Apart from this, sound categorization was also considered, however there are too many different sounds that have to be reliably categorized and implementing this and making it reliable enough to be used in the experiment is not possible within the time-scope of this project. After finding this and considering sound categorization, it was chosen to focus on frequency fluctuation. Sound will be recorded and the frequency will be estimated from this using Fast-Fourier transform (FFT) (Beard, 2004). FFT was chosen since it could be easily implemented in the Python recording script using already existing functions in the Numpy library.

3.2 Sub-question: Should background noise be filtered to reliably determine if a noise is distracting?

In this phase it was determined if background noise had to be filtered to obtain reliable data. In case the sounds had to be categorized (e.g. construction noise, dog barking, background music) it is possible that noise has to be filtered to obtain a accurate reading.

Since noise categorization was not being used, noise filtering was not necessary. It could still be useful to get a reliable reading on the microphone data and frequency estimation, but it is also very likely that because of the noise filtering, possible distracting sounds would get filtered. Therefore it was determined to not use background noise filtering.

3.3 Sub-question: If the background noise needs to be filtered, how can this be filtered without losing possible noises that distract a learner?

If from the previous research question it followed that background noise had to be filtered, another literature study had to be done to research what audio filtering techniques exist and how they can be applied using the following query: (auditory OR noise OR sound) AND filtering. The main goal was to find a way to filter noise, without removing sounds that possibly distract the learner. The search query may be expanded when more specific terminology is found in the papers.

Since it was determined that background noise will not be filtered, it was not necessary to study this.

3.4 Sub-question: Can a correlation between noise variation and distraction reliably be found in the microphone recordings?

To determine if distracting ambient noise can be measured and if these noises can be determined to be distracting, an experiment was held to collect data which should show if the correlation between ambient noise and distraction exists. For a full description of the process of this experiment, please refer to subsection 4.1. The ambient sound was recorded using two different microphones: a lavalier microphone and a common earphone microphone. The fluctuation in Hz and dB levels recorded during this test was studied and compared against the distraction-button data to find a correlation between sound measurements and distraction. When distraction could be determined from the recordings made with the lavalier microphone, it would also be tried if the same correlation holds for the earphone microphone. If this correlation could not easily be found by comparing the distraction button, played audio tags and microphone data, a machine learning algorithm needed to be found to find this correlation. If the data correlation can easily be found, a simple decision tree would have sufficed to automatically make a decision if a sound is distracting or not.

3.5 Sub-question: How does the correlation between noise variation and distraction help the multi-modal analytic tool to track sustained attention?

When the experiment was done and a possible correlation between noise distraction and audio data was found, this data would be compared against the results of the other 3 experiments. From there it would be determined if the audio data and it's decision algorithm can aid the overall system in detecting possible distractions. It was suspected that the possible correlation can aid in determining if someone is distracting if some other metric in the system already pointed out that someone is possibly distracted. It was also expected that the correlation would not be reliable enough to point out someone is distracted on its own.

4 Experimental setup

To determine if distracting ambient noise can be measured and if these noises can be determined to be distracting, an experiment was held to collect data which should show if the correlation between ambient noise and distraction exists. In this section, the process of the experiment and post processing and the details of the experiment setup will be described.

4.1 Experimental process

The experiment of this research was conducted via single-user testing. A single participant read a text in a quiet room while multiple sensors measured different metrics from the reader and his/her surroundings.

Ideally, these test would be conducted with as many different participants as possible, but due to COVID it was not possible to host participants outside of the research group. Therefore the researchers decided to conduct the experiments on themselves.

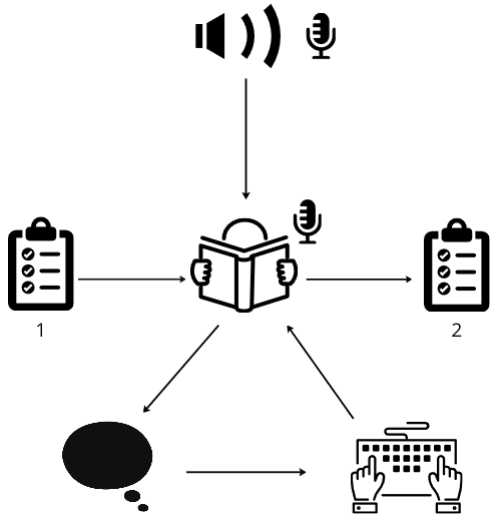

Figure 1: Diagram of the experimental setup

At the experiment, sound was recorded using two microphones: one lavalier microphone laying near a speaker and one earphone microphone laying next to the participant. The lavalier microphone was meant to record reliable data while the earphone microphone was used to determine if the found correlation also holds while recording with a more regularly available microphone in a learning environment. Before the experiments took place, the participant filled in a questionnaire about the text they where about to read. This first questionnaire was used to determine the prior knowledge the participant had on the text's topic. The questionnaires used in the experiment can be found at subsection C.4. When the questionnaire was made, the participant would start reading the text. Every participant read 3 texts lasting 45-90 minutes. The texts used in the experiment can be found at subsection C.3. When the participant felt distracted, he/she would press a button which would record the time of distraction in the Multi-modal Analytics tool. During the test 9 different sounds where played:

Category	Amount played	length (minutes:seconds)
Fluctuating tones	3	0:45
Relaxing song, meant to focus	1	1:30
White noise / relaxing sound fragment	1	0:45
Scary song	1	0:32 - 1:13
Construction sound	1	0:30 - 1:00
Text free song	1	0:45 - 1:00
Machine sound	1	0:22 - 0:45

Table 1: Different audio fragments played during the experiment.

The audio files used in the experiment can be found at https://github.com/MultimodalLearningAnalytics/ambient-audio-tracking/tree/master/audio As described before, the distracting aspect of sounds is the fluctuation in frequency, therefore during the test dB levels and frequency would be recorded. Frequency to determine the frequency fluctuation and dB levels to determine if there is an noise in the environment. Every participant tested a different change in fluctuating tones:

Participant	changing factor	step size	range	fragments (low frequency(Hz)-high frequency(Hz)-time interval(ms))
1	high-frequency	50 Hz	500 - 900 Hz	400-500-0500, 400-550-0500, 400-600-0500, 400-650-0500, 400-700-0500, 400-750-0500, 400-800-0500, 400-850-0500, 400-900-0500
2	low- and high-frequency	100 Hz	(200,300) - (1000,1100) Hz	200-300-0500, 300-400-0500, 400-500-0500, 500-600-0500, 600-700-0500, 700-800-0500, 800-900-0500, 900-1000-0500, 1000-1100-0500
3	time-interval	0.125 s	0.125 - 1.125 s	400-750-0125, 400-750-0250, 400-750-0375, 400-750-0500, 400-750-0625, 400-750-0750, 400-750-0875, 400-750-1000, 400-750-1125

Table 2: Different fluctuating audio fragments used per participant.

- Participant 1 got the same low-frequency and time-fluctuation-interval, the high-frequency would be changed to determine at what frequency difference a sound becomes distracting.
- Participant 2 got the same time interval for every sound and an equal difference in frequency between the low- and high-frequency. The low- and high-frequencies where incremented in steps of 100 Hz. This test was meant to determine if the height of the frequencies matters.

- Participant 3 got the same low- and high-frequency, but the time-fluctuation-interval was changed. The purpose of this test was to determine at which time-fluctuation-interval a sound becomes distracting.

The sound fragments where sorted incrementally by step. During the first read, fragment 1, 4 and 7 where played, during the second read, fragment 2, 5, and 8 would be played and during the last read, fragment 3, 6 and 9 would be played. The reason behind this, is that the participant would not notice that the frequency was different between the tests. This way a possible bias could be negated.

The audio fragments where played by hand at random time intervals of about 5 minutes. Every participant would not hear an audio fragment twice and the order of the type of audio fragment where to be shuffled in between the reading tasks.

After reading a text, the participant would make the same questionnaire he/she made before reading. The difference in answers between the two tests would be compared to verify that the participant was attentive during the experiment.

Unfortunately, during the experiment only one text per participant was read due to time constraints. To complete the audio recordings with the fluctuating audio fragments, a second text was read without making the questionnaire. The audio fragments where played in the originally intended order, however the time interval between the audio fragments was between 60-90 seconds.

4.2 Texts and questionnaire

Because this research was the only of the four parallel researches on this topic that introduced stimuli into the experiment, the researcher of this report opted to not partake in the research as a participant. The problem with the stimuli was that the researcher already had an opinion about the sounds that where going to be played and therefore could create a big bias in the recordings for this specific topic. It was also considered if someone else could create the sounds so the researcher was not aware of the sounds that where going to be played, but because the researcher wanted to have specific sounds to research and would still have an opinion on what should and should not be distracting, it was decided that this researcher would not take part in the experiment, but would monitor the experiment. The sounds that where going to be played and the hypothesis about the sounds where completely kept from the other researchers until after the experiment so they would not create a bias.

In exchange, the researcher was able to create the texts and questionnaires because it did not matter if he saw them before the experiment. It was crucial that the texts and questionnaires where kept from the participating researchers so they would not get too much information before the experiment.

The total experiment contained 3 experiment. The first two experiments where used to collect baseline values for distraction and for the deblur detection time while attentive and the last experiment was the experiment described above. Because no audio stimuli are introduced and because the deblur data was not used in this experiment, the first two experiments where not used in any way during this research. The researcher of this topic, however, did provide the small 30-60 second texts. These texts where collected by looking up tech articles on news sites. Tech articles where chosen to make sure the participating researchers would be interested in the text. In case this research would be redone with external participants,

are more general topic should be chosen to make sure the people stay attentive while reading the text.

For the third experiment, 3 texts and questionnaires where created. The three topics where Disney and the Disney parks, the ISS and the physical layer of computer networks. The first two texts (Disney and ISS) where constructed, mostly by copying paragraphs from wikipedia and adding additional text. The physical layer of computer networks text was a paragraph from the book Computer Networks, 5th edition by Tanenbaum. The texts where created to be around 45-90 minutes long.

The Disney topic was chosen because the researcher creating the texts was sure he knew enough about the topic to write additional paragraphs if necessary. Additionally the researcher was sure the participating researchers had not a lot of prior knowledge on this topic, helping the workings of the questionnaire. This topic is general enough that it can be reused in future research with outside participants. The ISS and physical layer topics where chosen because the researcher who created the texts was sure the participating researchers would be interested in these topics. The texts where in-depth enough to make sure the researches would be interested, but would not have enough prior knowledge to pass the questionnaire before the research. It is advised that the physical layer text is not used when using outside participants since this text would become to technical.

After the texts where created, the questionnaires where made. The questionnaires where made so about every 1 or 2 paragraphs there was a question (depending on the size of the paragraph and the possibility to make a question that can easily enough be remembered) to make sure the questions where spaced somewhat equal and the questionnaire could estimate a learners attention over the reading period. Questions where constructed to not be too specific and the answers where laying far enough apart so the learners could easily remember them after reading the text. Every question contained an option "I don't know" and the participants where constructed to fairly indicate when they did not know a question, to keep them from guessing.

During the actual experiment, only the Disney text was used because of time constraints. To finish the audio fragments with beeping constantly fluctuating frequency, the participants performed a small test where they read the ISS text for about 10 minutes. The remaining 6 audio fragments where played with random time intervals of around 60-90 seconds. During this experiment the questionnaire was not used since the participants would not be reading the full text and since there was not enough time to make them. The text and questionnaires can be found at subsection C.3 and subsection C.4.

4.3 Multi-modal platform

To perform the experiment and to do the multi-modal analysis, a multi-modal platform had to be chosen. The multi-modal platform had to support multiple big data streams including video and audio streams, be able to store its recordings, be able to add streams to the recordings after the experiment, be able to replay the data at a later moment, be able to easily visualize the recorded and processed data and support connections with other programming languages to allow processing. The researchers quickly landed on Microsoft PSI which suffices all the aforementioned requirements.

4.4 Laptop usage

For the experiment, a Lenovo Yoga 530-14ARR was used. This laptop was chosen because it was found that it was able to run the program and because it was available at the time. To record the sounds from the lavalier microphone and to play the audio fragments, a Dell Inspiron 15R N5010 was used. This laptop was again chosen because it was available at the time and since it was fast enough to run the required software. The two laptops where connected using an UTP cable with network sharing enabled on the Dell laptop. The Lenovo laptop functioned as a slave laptop over the network with the Dell essentially being a router. Both laptops ran Windows 10, Python 3.7.4 and PSI 0.15.49.1.

4.5 Microphone usage

To reliably record data, a good microphone needed to be chosen. It is essential that this microphone records equally in all directions so all ambient sound is recorded equally. This type of microphone is called an omni-directional microphone. One of the most readily available omni-directional microphones is a lavalier microphone, therefore a lavalier microphone was chosen to record the research data. Apart from the lavalier microphone, a commodity microphone like found in most earphones and laptops was used. This is to simulate a normal learning space, a regular student probably does not have a lavalier microphone hanging in the middle of his room. The recordings of the lavalier microphone was used to find a correlation between audio recordings and distraction, but the findings where compared with the earphone microphone to see if this correlation could still be detected in a regular learning space.

During the experiment, the AGPTEK Z02C-EU lavalier microphone was used. For the earphone microphone, the internal microphone of the Lenovo laptop mentioned in the last subchapter was used. Both microphones where recording with a resolution of 41000 Hz.

4.6 Code

All the code used for this research, both during the experiment and during post-processing can be found at the following GitHub repositories:

https://github.com/MultimodalLearningAnalytics/ambient-audio-tracking
https://github.com/MultimodalLearningAnalytics/rp-group-19-common

The first repo also contains the model trained during this research and the audio files played during the experiment.

5 Experimental Results

5.1 Questionnaire

The questionnaire made before and after the experiment was used to verify that the participant read the text and tried to be attentive while reading. The results of the questionnairs can be found at Appendix A. The average score before the experiment was a 1.3 while the average score after the experiment was a 7.6. This indicates that the participants read the text and tried to be attentive while doing so. It needs to be noted that question 19 and 22 where removed from the final results because nobody knew this question before nor after reading. In retrospect these questions are too specific and are therefore not considered in the final scores.

5.2 Uni-modal analysis

After the research, it was found that both participant 1 and 2 where distracted by 50-56% of the played sound fragments. Participant 3 was distracted by 70% of the sound fragments. This indicates that participant 3 is easily distracted by sounds and to determine if most people are distracted by an ambient sound, a more complicated modal then just detecting a hard sound will be necessary.

First it was tried if a correlation could be found by comparing the distraction button data and the data recording from the lavalier microphone by hand. Unfortunately a correlation was not clearly visible, so machine learning was needed.

For the machine learning, tensor flow was chosen. The reason for this, is that tensor flow has a tutorial with a simple kerbal model used to classify audio fragments ("Simple audio recognition: Recognizing keywords", 2021). The tutorial uses a dataset containing recordings of people saying simple commands. The dataset is shuffled and split into three separate sets: the training set, the validation set and the test set. These sets do not overlap and the size of these are respectively 80%, 10% and 10% of the total size of the dataset. The model uses the training set to train the model, it uses the validation set to validate the trained model during training and uses the test set to test the eventual accuracy of the model. Although this tutorial describes a way to train a model to do speech recognition, it can be used for general audio classification. Since this tutorial generates the spectogram of the audio fragments and then trains its model on the features of these spectograms, this code can also be adapted to be used for this research where audio frequencies are used to determine if a sound is distracting or not.

From the experimental recordings, 60 audio fragments of around 10 seconds where extracted, half of which are distracting, half of which are non distracting to keep the dataset balanced. First the distracting audio fragments where extracted by taking an audio fragment 5 seconds before, and 5 seconds after the distraction button was pressed. If the sound was smaller then 10 seconds, the fragment was made to fit the full distracting sound. From the same audio recording, an equal amount of non-distracting sounds where extracted. These included played audio fragments where the participant did not press the distraction during the fragment or right after the fragment, some audio spikes where the distraction button was not pressed and some static noise. Fragments where again taken to be 10 seconds long, unless the audio fragment was shorter then 10 seconds, in this case the fragment was again made to fit the full non-distracting audio.

The audio files where labeled by sorting them in different folders. Because the code did not accept 10 second files, the files where split up in 1 second files and ordered in folders by originating fragment to keep them together. The code was changed to first extract the original fragments, these 60 fragments are shuffled and after that the 1 second fragments are added to the overal dataset list. In this list, the 60 audio fragments are in the shuffled order, but the single second fragments are kept together to make sure the 1 second fragments of a 60 second fragment file are not spread over the 3 sets but are kept mostly in the same set. If the files would be spread, this would probably lead to a model that is validated and tested on 1 second fragments of 60 second fragments that also provide 1 second fragments to the training set. When the full dataset is build, the first 80% of the 1 second fragments will define the training set, the next 10% will define the validation set and the last 10% will define the test set.

There are two different metric that can be changed to define the training of the model: the batch size and the epochs. The batch size defines how many audio fragments will be considered before changing the values of the model and the epochs defines how many times the model will train on the training set. In case the epochs is 2, the model will train on the entire training set and when it is done it will continue training by going through the same training set again.

Multiple batch size and epochs values where tested, but a batch size of 19 and a epochs value of 3 were the only values that lead to a model that was not overfitted. The test set resulted in the following confusion matrix:

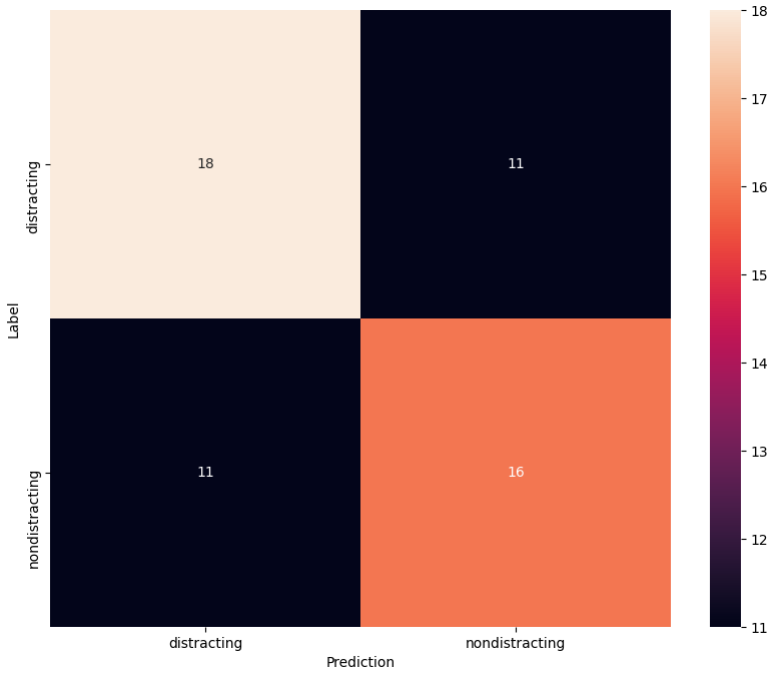

Figure 2: Confusion matrix of the test set

The precision, recall, F1-score and accuracy are can be calculated using this confusion ma-

trix (Sasaki, 2007):

- Precision: 62.07
- Recall: 62.07
- F1-score: 62.07
- Accuracy: 60.71 %

This means that there seems to be a correlation between audio frequency of microphone recordings and distraction and that this model can be used to predict if a sound is distracting or not distracting with a higher accuracy then guessing. The problem is that this can not be said with complete certainty. The dataset that is used to train, validate and test the model contains 548 1-second fragments. In comparison, the dataset used in the tutorial of the kerbal-model uses a dataset containing 105,000 audio files. The model looks promising and it seems like more data will improve it, but further research needs to be done to collect more data and provide the model with more data to give a more precise accuracy.

The predictions of the test was manually checked to see when it was right, and when it was wrong. For all audio fragments, except for the 400-850-0500 fragment, the majority of the predictions where correct. The model never saw the construction 3 sound and relaxing waterfall sounds, so this indicates that there may be a correlation between sounds frequency and distraction, but it still needs to be further researched with more data. For the analysis data, please refer to Appendix B.

The audio recodings of the lavalier microphone and the earphone microphone where compared and it was found that the recording are fairly similar. Therefore this model should still work when using an earphone microphone rather then a lavalier microphone.

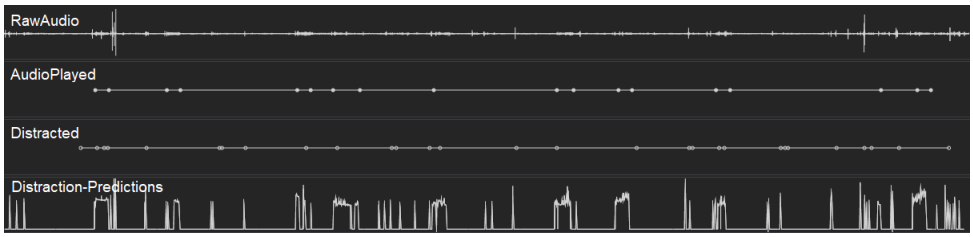

Figure 3: Visualization of the uni-modal model

5.3 Multi-modal analysis

When it came to the multi-modal analysis, unfortunately two of the four researches where not able to provide a model that could be used to perform a multi-modal analysis due to various reasons they ran into while training their models. For the specific reasons, please refer to their papers (van der Voort, 2021 and Toonder, 2021). Fortunately the ambient sound and mobile movement tracking models where available in time, so a multi-modal analysis could be performed using the models of these two researches.

As described in the previous chapter, the ambient sound model reached the following accuracy, recall, precision and f1-score:

- Precision: 62.07
- Recall: 62.07
- F1-score: 62.07
- Accuracy: 60.71 %

The mobile movement tracking had the following metrics:

- Precision: 98.57
- Recall: 86.25
- F1-score: 92.00
- Accuracy: 92.50 %

For more information on the mobile movement tracking model, please refer to the following paper (Deininger, 2021) To get to these scores, distracted was considered to be positive and non-distracted was considered to be negative. When considering non-distracted to be positive the precision of the ambient sound model becomes 59.26 and the precision of the mobile movement model becomes 87.78.

From these scores, it becomes clear that the mobile movement model perform significantly better then the audio model. When comparing the outcomes of the models to the data stream containing the distraction button presses, it becomes clear that the mobile movement model detects most distraction points, but misses some. Luckily the audio model does detect these points, but it also detects some points that are not be distracting. Because the mobile movement tracking model is significantly more accurate then the audio model, it was decided that the phone model would become the dominant model. This means every data-point on the mobile movement detection stream is combined with the nearest data-point in the future of the audio model. This way every data-points of the mobile movement detection model is considered in the multi-modal analysis. Using the previously calculated scores, the following model was created. It needs to be noted that the scores are floats between 0 and 1 which describe the predicted change of the model that the data given indicates distraction. In this case if the score is below 0.5, it means that the model predicts the data to indicate non-distraction:

Case	Multi-modal score
P >= 0.5	P
P < 0.5 and A >= 0.5	((87.78 * P) + (62.07 * A)) / (87.78 + 62.07)
P < 0.5 and A < 0.5	((87.78 * P) + (59.26 * A)) / (87.78 + 59.26)

Table 3: Multi-modal model (P: score of the mobile movement tracking model output, A: ambient audio model output)

The weights in the weighted averages in this model are determined by the precision of

the model. In case a model predicts above 0.5 (distracted), the precision considering distracted to be positive will be used, in case the model predicts below 0.5 (non-distracted), the precision considering non-distracted to be positive will be used.

Because the mobile movement tracking model was significantly more precise then the audio model, it was decided that the audio model would take on more of a supportive role. In case the phone model detects a distraction, it is assumed to be true. In case the phone model does not detect a distraction, the weighted average of the phone and audio models are used. This way the audio model can only add a distraction to the uni-modal model when it is completely sure.

By using the uni-modal model, the accuracy of the mobile movement detection model and the audio detection model increased. Most distracting points that where not picked up by the mobile movement detection model where picked up by the uni-modal model because of the weighted average of the two models.

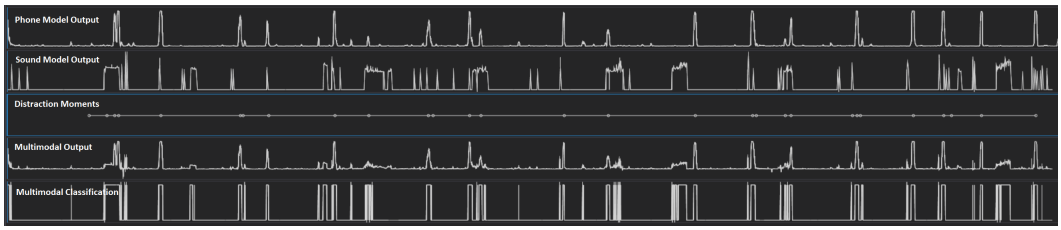

Figure 4: Visualization of the multi-modal model

6 Responsible Research

In this section the ethical implications and reproducibility of this research will be discussed.

6.1 Ethical implications

The main goal of this research was to determine if someone is distracted by recording ambient sound using a microphone. The problem with audio recordings is that these can contain sensitive data about the participant, anything the participant says will be recorded. To make sure no sensitive data would be recorded, it was made sure that the final recordings did not contain any moment at which the participant was speaking. If the recording contained such data, the section containing the participants speech was immediately deleted. It was also made sure that the participant did not perform any task other then reading while recording so possible sensitive audio created by private tasks where recorded.

Apart from the first ethical implication, it also needs to be mentioned that (as described in section 5) there was not enough data to come to a full conclusion and there where not enough different participants, so a possible bias can be present in the dataset. All the participants where also part of the same demographic group (male, early 20s, CSE student) so it is also possible that the model contains a bias towards this group. The researchers are aware of this and hereby warn the reader that the result can not be threaded as conclusive and that further research with a bigger dataset and more participants with a more representative participant group are necessary to come to a full conclusion.

6.2 Reproducibility

Because of the size of the dataset used (553 GB) and because these datasets may contain sensitive personal data of the participants (in this case the researchers), it is chosen to not provide these sets. These sets will be available on request by sending a email to j.s.pronk[at]student.tudelft.nl. Although the datasets will be available on request, the trained model and all the source code used during this project, including the source code used for the other researches that are combined into the multi-modal model, can be found at the following GitHub repositories:

https://github.com/MultimodalLearningAnalytics/ambient-audio-tracking
https://github.com/MultimodalLearningAnalytics/rp-group-19-common

7 Discussion

7.1 Uni-modal analysis

Previous research found that people can get distracted by non-vocal audio. The distracting factor was found to be frequency fluctuation (Perham et al., 2007). The model trained in this experiment slightly confirms this claim by training and predicting on frequency spectograms of the audio recordings. Unfortunately, because of the lack of a bigger dataset with enough audio fragments to properly train a kerbal model, this claim can not be made conclusive, but while going through the prediction data of the test set, the model seemed promising. It also needs to be considered that only three participants where used and that the all fall roughly fall in the same demographic group (male, early 20s, CSE students). This could have created a possible bias towards this demographic group. Future research should use a more representative participant group. It is expected that the model can be improved to make a reliable prediction on distracting sounds, but further research is necessary to confirm this hypothesis.

7.2 Multi-modal analysis

By combining the audio tracking model with the mobile movement tracking model, it was found that combining these two models resulted in a more reliable and accurate model. Especially from the audio models perspective, the accuracy seemed to improve significantly. The exact model is not expected to work anymore when both models are improved, but the method used in this research to get the multi-modal model should still suffice when the models improve. The only thing that needs to be changed if the audio models accuracy increases to match the mobile movement model is that an weighted average should also be used when the mobile movement model predicts a distraction. It would have been interesting to see how the model would have developed if the other two researches where included. Because of the positive results of the created multi-modal model, it is expected that adding more sensor models will increase the accuracy of the model.

8 Conclusions and Future Work

In this chapter, the research questions will be reviewed and answered, leading to a concluding answer on the main research question. After the some recommendations for future research will be given. Since one of the 5 sub-questions ended up not being use full for the research, these will be excluded. For more information please refer to section 3

8.1 Conclusions

8.1.1 Sub-question: What should be measured on the noise (dB, Hz, Hz fluctuation or categorized sounds or something else?) ?

After some literature study, it was found that the distracting factor of noise is the frequency fluctuation (Perham et al., 2007). Since it was found that frequency if the distrating factor, it was determined that the rest of the research focused on recording the raw audio and estimating it's peak frequency. By analyzing the frequencies of the raw audio recordings, it would be tried if a correlation between audio and distraction could be found.

8.1.2 Sub-question: Should background noise be filtered to reliably determine if a noise is distracting?

Since noise categorization is was not going to being used, noise filtering was not necessary. Maybe it could still have been use full to filter out noise in the recordings, however this is a dangerous move since this could also mean that a possibly distracting sound could be filtered out. Therefore it was decided that the raw data, without any processing or filtering would be used for the research.

8.1.3 Sub-question: Can a correlation between noise variation and distraction reliably be found in the microphone recordings?

To determine if distracting ambient noise can be measured and if these noises can be determined to be distracting, an experiment was held to collect data which should show if the correlation between ambient noise and distraction exists. Because the recordings and estimated peak frequency alone where not enough to determine if a sound was distracting, a kerbal model was trained using tensor flow to classify audio fragments as being either distraing or non distracting. This model had a accuracy of 61% and is therefore better then guessing if a sound is distracting or not, although it should be mentioned that the dataset was to small to definitively determine if the correlation properly exists.

8.1.4 Sub-question: How does the correlation between noise variation and distraction help the multi-modal analytic tool to track sustained attention?

When the experiment was done and a possible correlation between noise distraction and model was trained to predict if a sound is distracting or not, this model was compared against the mobile movement detection model. Because the accuracy of the audio model was significantly smaller then the accuracy of the other model, the audio model can only slightly help the multi-modal model in case the mobile movement detection model does not detect a distraction. The fact that the audio model detected most distractions the mobile movement detection model could not detect indicates that the two models could be combined to create a more accurate model. More research on this has to be done however to create

more accurate models and see if the models still need to help each other. In the case the audio model would become more accurate, this could lead to a more complex model in which the multi-modal score is not only determined by the mobile movement detection model, but also by the audio model.

8.1.5 Main research question: How can ambient noise sensing aid in a multi-modal analytics tool to track sustained attention?

Using the aformentioned sub question the main research question can be anwered. A correlation between ambient noise and distraction was found using a kerbal model, although further research needs to clarify if this 61% accuracy will also hold up or become better when using a significantly bigger dataset to train the model.

Because of the low accuracy and of the higher accuracy of the other model, it can be concluded that ambient noise sensing can aid a multi-modal analytics tool adding additional distractions in case the mobile detection model is not sure, but the audio model is completely sure. The uni-modal audio model can be adapted to predict in real time if audio recorded by a microphone is distracting although it should be mentioned that further research is necessary to confirm this claim.

From further research it can either follow that using a bigger dataset uni-modal can singly detect distractions and can help the multi-modal analytics tool by deciding when a subject is distracted, or it can follow that the accuracy of the model is lower and ambient noise sensing can not be used to track sustained attention.

The created model was used to create a multi-modal model by combining it with the model created in the mobile movement tracking research (Deininger, 2021). Since the mobile movement tracking model is significantly more accurate then the audio tracking model, the audio tracking model aids the mobile movement tracking model in case it does not detect a distraction. In these cases the weighted averages of the two models where used as the output of the multi-modal model. The weights where assigned using the models precision. By doing this, the ambient noise sensing model was able to detect some distracting points that the mobile movement tracking model did not pick up. So to conclude, the ambient noise sensing can aid the multi-modal analytics tool to track sustained attention by detecting some distractions the mobile movement tracking model did not detect.

Future research is necessary to see what would happen in case more data is available and the models of the other two researches (Toonder, 2021 and van der Voort, 2021) can be added.

8.2 Future Work

8.2.1 Dataset size

As described in section 5, the model is only trained on 548 audio fragments which is too low to properly train a model. The researchers are aware of this and advice future research to gather more data using more different distracting sounds to train a better, hopefully more accurate model. During future research it should be considered that more different sounds should be used then the amount of fragments used in this research to make sure the model will still extract features, rather then detecting specific audio fragments. Because every audio fragment during this experiment was only played ones, this should not be an issue for this specific experiment, but it is something that future research needs to be aware of.

8.2.2 Amount of participants and their demographic

As described in section 3, the research is only conducted on the 3 researchers. Due to the COVID-19 pandemic it was not possible to invite participants to conduct the research. This limited the amount of data that could be gathered and resulted in a unrepresentative group. Because of this, it is possible that there exists a bias in the dataset towards certain characteristics of the participant (people being more or less distracted by noise). It also needs to be considered that the participants are all part of the same demographic group (male, early 20s, CSE student). This could also lead to a possible bias towards this demographic group. In future research more test subjects need to be used to make sure such a bias does not exist. It is also necessary that the group of participants form a more representative group.

8.2.3 Additional multi-modal analysis

In case new models are created in future research, the multi-modal model should also be reconsidered. In case the other two models can be fixed, these should be included. In case the audio model's precision significantly increases or if the mobile movement detection models precision significantly decreases, the model should be adapted to also calculate a weighted average in case the mobile movement detection model predicts a detection.

9 Acknowledgment

This research would not have been possible without the help of my peers Giuseppe Deininger, Jurriaan Den Toonder and Sven van der Voort. Thank you all for your contributions on the code, peer reviews and for thinking along when necessary. This research would also not have been possible without the supervisor Yoon Lee and responsible professsor Marcus Specht. Thank you for your insights, for thinking along and coming up with ideas to improve the research.

References

Beard, J. K. (2004). *The fft in the 21st century*. Springer. https://doi.org/10.1007/978-1-4757-6734-6

Bronkhorst, A. W. (1999). The cocktail party effect: Research and applications. *The Journal of the Acoustical Society of America*, *105*(2), 1150â1150. https://doi.org/10.1121/1.425470

Deininger, G. (2021). Assessing learnerâs distraction in a multimodal platform for sustained attention in the remote learning context using mobile devices sensors.

Ke, J., Zhang, M., Luo, X., & Chen, J. (2021). Monitoring distraction of construction workers caused by noise using a wearable electroencephalography (eeg) device. *Automation in Construction*, *125*, 103598. https://doi.org/10.1016/j.autcon.2021.103598

Lee, Y. (2019). Noise fatigue in the icu: Platform for sound data collection and visualization. https://repository.tudelft.nl/islandora/object/uuid:3f36cd36-d668-457c-a795-39ff3ba2%20683c?collection=education

Min, C. O., Hwasoon, K., Whee, L. Y., & Insook, C. (2016). Clinical alarms in intensive care units: Perceived obstacles of alarm management and alarm fatigue in nurses. *Healthc Inform Res*, *22*(1), 46–53. https://doi.org/10.4258/hir.2016.22.1.46

Morgan, J. J. B. (1917). The effect of sound distraction upon memory. *The American Journal of Psychology*, *28*(2), 191–208. http://www.jstor.org/stable/1413720

Perham, N., Banbury, S. P., & Jones, D. M. (2007). Reduction in auditory distraction by retrieval strategy [PMID: 17469024]. *Memory*, *15*(4), 465–473. https://doi.org/10.1080/09658210701288244

Sasaki, Y. (2007). The truth of the f-measure. https://www.toyota-ti.ac.jp/Lab/Denshi/COIN/people/yutaka.sasaki/F-measure-YS-26Oct07.pdf

Schneider, J., Börner, D., Rosmalen, P. V., & Specht, M. (2015). Augmenting the senses: A review on sensor-based learning support. *Sensors*, *15*(2), 4097–4133. https://doi.org/10.3390/s150204097

Simple audio recognition: Recognizing keywords. (2021). https://www.tensorflow.org/tutorials/audio/simple_audio

Toonder, J. D. (2021). Camera-based face and infrared temperature sensing of learnerâs affective state in the remote learning context using machine learning.

van der Voort, S. (2021). Tracking sustained attention with webcam-based eye gaze and blink pattern tracking.

A Questionnaire results

Tijdstempel	Please fill in your name	after	How many brothers and sisters did Walt Disney have?	What did Disney have to draw for his first Drawing job?	Who introduced Disney to the world of motion picture?	Why was Disney rejected to fight in WW1	cartoons Disney produced?	Disney created?	What was the original name of Mickey Mouse?	What cartoon was the first Disney cartoon to feature synchronized sound?
01/06/2021 15:43	Participant 2	Before	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know
01/06/2021 16:55	Participant 2	After		I don't know	I don't know	He was too young	Laugh-O-Grams	Mickey Mouse	Mortimer Mouse	I don't know
01/06/2021 16:24	Participant 1	Before	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know
01/06/2021 18:06	Participant 1	After		Horse	I don't know	He was too young	Laugh-O-Grams	Oswald the Rabbit	Mortimer Mouse	I don't know
01/06/2021 19:10	Participant 3	Before	I don't know	I don't know	I don't know	I don't know	Mickey mania	Mickey Mouse	Mortimer Mouse	Steamboat Willie
01/06/2021 20:45	Participant 3	After		I don't know	A friend from school	He was too young	Laugh-O-Grams	Oswald the Rabbit	Mortimer Mouse	I don't know

Tijdstempel	Please fill in your name	Before or after reading?	What was the first feature length cartoon Disney created?	How did Disney created a sense of depth in its cartoons?	Which cartoon's production was shortly halted due to a strike of the staff?	During WW2, Disney created propaganda for the US. Which Disney character was prominently featured in these cartoons?	What link did Disney have with the FBI?	In 1951 Disney created a movie he wanted to produce from the beginning of his movie-making career. What movie was this?	When did Disney come up with the idea for Disneyland (as the story goes, while ...)	Did Disney ever visit the Efteling and what is the story behind it?
01/06/2021 15:43	Participant 2	Before	I don't know	By adding multiple layers of drawings to the camera that could move independently, background layers and foreground were separate, partially transparent, drawings	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know
01/06/2021 16:55	Participant 2	After	I don't know	By adding multiple layers of drawings to the camera that could move independently, background layers and foreground were separate, partially transparent, drawings	Dumbo	Donald Duck	He secretly passed information to the FBI	I don't know	While sitting on a bench, watching his kids ride the Merry-go-round	No he did not, it was a misunderstanding of the press
01/06/2021 16:24	Participant 1	Before	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know
01/06/2021 18:06	Participant 1	After	Snow White	By hire drawing the images, consistently moving the background respect wity of the character (single drawing)	Bambi	Donald Duck	He secretly passed information to the FBI	Alice in Wonderland	While sitting on a bench, watching his kids ride the Merry-go-round	No he did not, it was a misunderstanding of the press
01/06/2021 19:10	Participant 3	Before	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know
01/06/2021 20:45	Participant 3	After	Snow White	By adding multiple layers of drawings to the camera that could move independently, background layers and foreground were separate, partially transparent, drawings	Dumbo	Donald Duck	He secretly passed information to the FBI	Alice in Wonderland	While sitting on a bench, watching his kids ride the Merry-go-round	No he did not, it was a misunderstanding of the press

Tijdstempel	Please fill in your name	Before or after reading?	What does WED enterprises stand for and what was the main goal of this company?	What TV broadcasting company did Disney work with to fund Disneyland?	What sports-event was Disney involved in?	How many rides did Disney create for the New York World's Fair?	Why did the original PeoplemoverRocket Rolls have to close?	What does the acronym EPCOT stand for?	What probably caused the death of Disney?	What remnant of the original idea of EPCOT can still be found and where?
01/06/2021 15:43	Participant 2	Before	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know
01/06/2021 16:55	Participant 2	After	I don't know	ABC	I don't know	I don't know	Problems with the construction	I don't know	Heavy smoking	I don't know
01/06/2021 16:24	Participant 1	Before	I don't know	I don't know	Basketball	I don't know	I don't know	I don't know	I don't know	I don't know
01/06/2021 18:06	Participant 1	After	Walt's Envisioning Department, the company came up with new ideas for cartoons and other movies	I don't know	Olympic games	I don't know	I don't know	Experimental Prototype Community Of Tomorrow	Heavy smoking	I don't know
01/06/2021 19:10	Participant 3	Before	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know
01/06/2021 20:45	Participant 3	After	I don't know	ABC	I don't know	I don't know	Safety issues with the rocketship	Experimental Prototype Community Of Tomorrow	Heavy smoking	A maquette of the original plans, in the peoplemover in Orlando

Tijdstempel	Please fill in your name	Before or after reading?	Removed...too specific Disney often operated a specific ride in Disneyland? Which ride?	What happened to the roads on opening day?	What was the main complaints about the rides in Disneyland?	Removed...too specific What was an additional complaint about the Snow White ride?	Why was club 33 created?	What memorial of Walt Disney can be found in Disneyland?	Which country where the last to be considered for Disneyland in Europe, besides France?	Why was Paris chosen for Disneyland?
01/06/2021 15:43	Participant 2	Before	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know
01/06/2021 16:55	Participant 2	After	The steamtrain	The roads started melting	The main characters of the ride where nowhere to be found	It was too scary for children	To have a place that served alcohol in the park, off limits of the regular guests	A light that symbolizes Walt's spirit and presence at Disneyland	Spain	It's central location in Europe
01/06/2021 16:24	Participant 1	Before	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know
01/06/2021 18:06	Participant 1	After	The peoplemover	The roads started melting	The main characters of the ride where nowhere to be found	It was too scary for children	To have a place that served alcohol in the park, off limits of the regular guests	A light that symbolizes Walt's spirit and presence at Disneyland	Spain	It's central location in Europe
01/06/2021 19:10	Participant 3	Before	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know
01/06/2021 20:45	Participant 3	After	The steamtrain	The roads started melting	The main characters of the ride where nowhere to be found	It was too scary for children	To have a place that served alcohol in the park, off limits of the regular guests	A light that symbolizes Walt's spirit and presence at Disneyland	Spain	It's central location in Europe

Tijdstempel	Please fill in your name	Before or after reading?	What theme was exclusively used for the hotels in Disneyland Paris?	Where were the recipes for DP (Disneyland Paris) originally tested?	In which three european countries where employees sought?	What concern did the french have on DP?	What can be said about the crowd-level on the openingday of DP	What was one of the complaints about the food in DP?	What incorrect assumptions did Disney make about European people when they made DP?	What is the "tomorrowland issue" and how is this solved in DP?
01/06/2021 15:43	Participant 2	Before	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know
01/06/2021 16:55	Participant 2	After	American	Test kitchens in Walt Disney World, Orlando	France, Netherlands, Spain	Cultural Imperialism	Hyper then expected	No wine was served at diner	The travel distance people find long distance was lower then expected	I don't know
01/06/2021 16:24	Participant 1	Before	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know
01/06/2021 18:06	Participant 1	After	American	I don't know	France, UK, Netherlands	Cultural Imperialism	Lower then expected	No wine was served at diner	The travel distance people find long distance was lower then expected	"tommorow" aging too fast, making Discoveryland, a steam-punk/alternate version of the future.
01/06/2021 19:10	Participant 3	Before	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know
01/06/2021 20:45	Participant 3	After	American	Test kitchens in Walt Disney World, Orlando	I don't know	Cultural Imperialism	Lower then expected	No wine was served at diner	The travel distance people find long distance was lower then expected	"tommorow" aging too fast, making Discoveryland, a steam-punk/alternate version of the future.

Tijdstempel	Please fill in your name	Before or after reading?	What ride mostly sawed DP from closure?	Why was the Walt Disney Studios Park build?	Why did both parks on the paris resort close for the first time?	Which 3 new IP's (Intellectual Properties) where announced for the Walt Disney Studios Park in 2018?	What are Jeffrey's expectations about the fate of the studio tram tour ride?	How many times did DP close due to COVID?	Is DP currently opened?
01/06/2021 15:43	Participant 2	Before	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know
01/06/2021 16:55	Participant 2	After	Space Mountain	They where obligated because of a contract with the French government	November 2015 paris attacks (Bataclan)	Frozen, Star Wars, Marvel	I don't know	2	I don't know
01/06/2021 16:24	Participant 1	Before	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know	I don't know
01/06/2021 18:06	Participant 1	After	Indiana Jones miExcoaster	I don't know	Because of an unfortunate accident on the Railroad	I don't know	It is a cheap overhaul to keep capacity, will be closed when capacity of the park is up	2	No
01/06/2021 19:10	Participant 3	Before	I don't know	I don't know	I don't know	I don't know	I don't know	2	Partially, just outside attractions are opened
01/06/2021 20:45	Participant 3	After	Space Mountain	I don't know	November 2015 paris attacks (Bataclan)	Frozen, Star Wars, Marvel	It is a cheap overhaul to keep capacity, will be closed when capacity of the park is up	2	No

Tijdstempel	Please fill in your name	Before or after reading?	Correct	Score (1-10)
01/06/2021 15:43	Participant 2	Before	1	1,2
01/06/2021 16:55	Participant 2	After	30	7
01/06/2021 16:24	Participant 1	Before	0	1
01/06/2021 18:06	Participant 1	After	31	7,2
01/06/2021 19:10	Participant 3	Before	3	1,6
01/06/2021 20:45	Participant 3	After	38	8,6

B Prediction data

Values generated by model	Prediction	True value	Fragment name	Correct	Fragment description
[1.95845842e+00 -5.84748447e-01]	distracting	distracting	d-p1-am-03-01	TRUE	400-750-0500
[2.08731759e-02 5.57374731e-02]	non-distracting	distracting	d-p1-am-03-02	FALSE	400-750-0500
[-2.36592088e-02 1.34853929e-01]	non-distracting	distracting	d-p1-am-03-03	FALSE	400-750-0500
[2.56933749e-01 -8.28885064e-02]	distracting	distracting	d-p1-am-03-04	TRUE	400-750-0500
[2.82820333e-02 4.99743596e-02]	non-distracting	distracting	d-p1-am-03-05	FALSE	400-750-0500
[4.65242658e-04 6.36887923e-02]	non-distracting	distracting	d-p1-am-03-06	FALSE	400-750-0500
[1.74437061e-01 -2.07876321e-02]	distracting	distracting	d-p1-am-03-07	TRUE	400-750-0500
[1.47468388e+00 -6.11259997e-01]	distracting	distracting	d-p1-am-03-08	TRUE	400-750-0500
[9.47002023e-02 3.02567016e-02]	distracting	distracting	d-p1-am-03-09	TRUE	400-750-0500
[2.84312785e-01 -4.49891277e-02]	distracting	distracting	d-p1-am-03-10	TRUE	400-750-0500
[-2.19435990e-01 1.94781154e-01]	non-distracting	distracting	d-p2-01-04-01	FALSE	construction 3
[1.47478366e+00 -6.06148779e-01]	distracting	distracting	d-p2-01-04-02	TRUE	construction 3
[8.69332626e-02 2.41767634e-02]	distracting	distracting	d-p2-01-04-03	TRUE	construction 3
[1.47512424e+00 -6.06801629e-01]	distracting	distracting	d-p2-01-04-04	TRUE	construction 3
[1.43359566e+00 -5.96199036e-01]	distracting	distracting	d-p2-01-04-05	TRUE	construction 3
[4.69872020e-02 5.43085374e-02]	non-distracting	distracting	d-p2-01-04-06	FALSE	construction 3
[7.93114491e-03 5.39992079e-02]	non-distracting	distracting	d-p2-01-04-07	FALSE	construction 3
[8.29293609e-01 -2.12947771e-01]	distracting	distracting	d-p2-01-04-08	TRUE	construction 3
[1.18147675e-02 8.39998052e-02]	non-distracting	distracting	d-p2-01-04-10	FALSE	construction 3
[4.15932119e-01 -1.21238194e-01]	distracting	distracting	d-p2-01-06-01	TRUE	relaxing waterfall
[1.44870090e+00 -5.99944115e-01]	distracting	distracting	d-p2-01-06-02	TRUE	relaxing waterfall
[6.23368174e-02 4.41707596e-02]	distracting	distracting	d-p2-01-06-03	TRUE	relaxing waterfall
[2.90870100e-01 -4.88860272e-02]	distracting	distracting	d-p2-01-06-04	TRUE	relaxing waterfall
[8.51784945e-02 1.39832590e-02]	distracting	distracting	d-p2-01-06-05	TRUE	relaxing waterfall
[-2.18896359e-01 1.94747239e-01]	non-distracting	distracting	d-p2-01-06-06	FALSE	relaxing waterfall
[9.62835178e-02 2.82005612e-02]	distracting	distracting	d-p2-01-06-07	TRUE	relaxing waterfall
[-1.49127185e-01 1.47726342e-01]	non-distracting	distracting	d-p2-01-06-08	FALSE	relaxing waterfall
[1.43528318e+00 -5.98225594e-01]	distracting	distracting	d-p2-01-06-09	TRUE	relaxing waterfall
[1.44856906e+00 -6.06392086e-01]	distracting	distracting	d-p2-01-06-10	TRUE	relaxing waterfall
[-2.20335990e-01 1.95485711e-01]	non-distracting	non-distracting	n-p1-01-01-01	TRUE	Doors slamming at 6:05
[2.37819672e+00 -7.21238494e-01]	distracting	non-distracting	n-p1-01-01-02	FALSE	Doors slamming at 6:05
[-2.20203787e-01 1.95787922e-01]	non-distracting	non-distracting	n-p1-01-01-03	TRUE	Doors slamming at 6:05
[6.96589947e-02 2.65153479e-02]	distracting	non-distracting	n-p1-01-01-04	FALSE	Doors slamming at 6:05
[-1.74971730e-01 1.61226049e-01]	non-distracting	non-distracting	n-p1-01-01-05	TRUE	Doors slamming at 6:05
[-2.19644442e-01 1.95361853e-01]	non-distracting	non-distracting	n-p1-01-01-06	TRUE	Doors slamming at 6:05
[-2.19423383e-01 1.95448324e-01]	non-distracting	non-distracting	n-p1-01-01-07	TRUE	Doors slamming at 6:05
[-1.82335377e-01 1.74273968e-01]	non-distracting	non-distracting	n-p1-01-01-08	TRUE	Doors slamming at 6:05
[1.48169482e+00 -6.11514390e-01]	distracting	non-distracting	n-p1-01-01-09	FALSE	Doors slamming at 6:05
[-2.19689935e-01 1.95241556e-01]	non-distracting	non-distracting	n-p1-01-01-10	TRUE	Doors slamming at 6:05
[1.18416408e-03 7.58877993e-02]	non-distracting	non-distracting	n-p1-am-03-01	TRUE	400-850-0500
[9.60053727e-02 2.65146699e-02]	distracting	non-distracting	n-p1-am-03-02	FALSE	400-850-0500
[5.72432093e-02 3.19958627e-02]	distracting	non-distracting	n-p1-am-03-03	FALSE	400-850-0500
[8.73635188e-02 1.52766760e-02]	distracting	non-distracting	n-p1-am-03-04	FALSE	400-850-0500
[-1.31970704e-01 1.39222816e-01]	non-distracting	non-distracting	n-p1-am-03-05	TRUE	400-850-0500
[1.42139995e+00 -5.94643056e-01]	distracting	non-distracting	n-p1-am-03-06	FALSE	400-850-0500
[2.09249407e-01 -2.94423085e-02]	distracting	non-distracting	n-p1-am-03-07	FALSE	400-850-0500
[-2.19921589e-01 1.95527554e-01]	non-distracting	non-distracting	n-p1-am-03-08	TRUE	400-850-0500
[-1.08673669e-01 1.29991651e-01]	non-distracting	non-distracting	n-p1-am-03-09	TRUE	400-850-0500
[1.48417830e+00 -6.21152937e-01]	distracting	non-distracting	n-p1-am-03-10	FALSE	400-850-0500
[-2.20111251e-01 1.95656657e-01]	non-distracting	non-distracting	n-p3-01-01-01	TRUE	Resitting (6:16)
[-2.19849110e-01 1.95246607e-01]	non-distracting	non-distracting	n-p3-01-01-02	TRUE	Resitting (6:16)
[3.49798977e-01 -1.19458854e-01]	distracting	non-distracting	n-p3-01-02-01	FALSE	random spike (11:30)
[-1.89717233e-01 1.77423567e-01]	non-distracting	non-distracting	n-p3-01-02-07	TRUE	random spike (11:30)
[-1.54254168e-01 1.55146748e-01]	non-distracting	non-distracting	n-p3-01-02-08	TRUE	random spike (11:30)
[-1.89110607e-01 1.70644790e-01]	non-distracting	non-distracting	n-p3-01-02-09	TRUE	random spike (11:30)
[2.74762865e-02 5.55830598e-02]	non-distracting	non-distracting	n-p3-01-02-10	TRUE	random spike (11:30)

C Experiment texts and questionnaires

The following contains the texts and questionnaires used during the experimental phase of this project. The writer of this report does not own the full rights to any of the texts provided. The source of the text is provided after every text!

C.1 Experiment 1

C.1.1 Biden test drives Ford

President Joe Biden was filmed taking Ford's all-electric new Lightning pickup truck for what looked like a high-speed run down a stretch of pavement during a visit to Ford's Rouge factory in Dearborn, Michigan on Tuesday.

While Biden is known as a bit of a Corvette fiend, he seems to be enjoying himself behind the wheel of a vehicle with enough torque to make even a big block C2 quake in its boots. Even better, the Lightning looks quick enough that even the Secret Service was forced to scramble to keep up, in a video clip posted to Twitter by C-SPAN.

What was the presidential verdict after taking the Lightning for a spin? "This sucker's quick!" he exclaimed, adding that he'd buy one. A reporter asked how quick it was, and Biden said it did 0-60 mph in 4.3 or 4.4 seconds, looking to a Ford employee for clarification, who quickly declined to comment. The president then did a hard launch from a stop right in front of the press pool, accelerating to 80 mph.

https://www.cnet.com/roadshow/news/biden-test-drives-ford-f150-lightning-electric-pickup/

C.1.2 Google tackles fake new in search

Google is making it easier for people to evaluate information and check the sources for results that show up on its massive search platform, the company said during the Google I/O developer's conference keynote on Tuesday.

When you search for something on Google, a new feature called About this Result will appear under a given website in your results list. This will show you how the site describes itself, what other sites say about it, and its Wikipedia page, so you can make a more informed decision about which sites to trust. About this Result will begin rolling out over time.

An update to Google Lens, the AR-powered camera recognition feature that helps you identify plants and animals or translate text on a printed page, will add new capabilities to help you quickly search, copy or listen to text you've just translated. The update will launch globally this month on Android devices, and later this summer on iOS.

https://www.cnet.com/news/google-tackles-fake-news-in-search-update-heres-how-it-works/

C.1.3 Citizen app palisades fire wrongly

The vigilante crime app Citizen falsely accused a California man of starting a wildfire, offering a $30,000 reward to track him down before retracting the post the next day, in a move that has been condemned by criminal justice experts.

The app - which gives users local crime information via police scanners and other sources - shared an alert on Saturday about an alleged arsonist behind a large brush fire that broke out in Los Angeles over the weekend.

The suspect, who is homeless, was briefly detained by officials who ultimately found there was not enough evidence to tie him to the crime, the Los Angeles fire department confirmed to the Guardian. A different suspect has since been arrested.

But that was not before the falsely accused man had his name and image widely shared. The alert sent by Citizen contained a photo and was seen by more than 861,000 people. It read: "Citizen is offering a $30,000 reward to anyone who provides information that leads to the arrest of the arson suspect."

https://www.theguardian.com/technology/2021/may/18/citizen-app-palisades-fire-wrongly-accused-man

C.1.4 UK covid related cybercrime

The UK's cybersecurity agency has taken down more scams in the last year than in the previous three years combined, with coronavirus and NHS-themed cybercrime fuelling the increase.

Experts oversaw a 15-fold rise in the removal of online campaigns compared with 2019, according to the National Cyber Security Centre (NCSC).

There was a jump in the number of phishing attacks using NHS branding to dupe victims, with the Covid-19 vaccine rollout used as a lure via email and text message to harvest people's personal information for fraud.

Forty-three fake NHS Covid-19 apps hosted outside of official app stores were also pulled.

"The big increase in Covid-19-related scams, fake vaccine shops, fake PPE shops, show - to me anyway - that criminals have no bounds on what they will abuse and the fear that they engender to try and harm and defraud people," Dr Ian Levy, the technical director of the NCSC told reporters.

https://www.theguardian.com/technology/2021/may/10/uk-covid-related-cybercrime-fuels-15-fold-rise-in-scam-takedowns

C.1.5 Jake Paul investigated

YouTuber Jake Paul is being investigated after posting a video on social media apparently showing him driving around a protected beach in Puerto Rico.

Driving is illegal on some of the island's beaches, as turtles nest in the sand.

The local Department of Natural and Environmental Resources said it would investigate whether the law had been broken.

Paul has been contacted for comment. Protected species

The Instagram video showed Paul and a group of people driving around in two vehicles on a beach. The post now been removed.

Turtle nesting and hatching season is between February and August in Puerto Rico and its beaches attract several protected species, including the endangered leatherback.

The video was widely shared online and many criticised the Youtuber-turned-boxer for putting the reptiles at risk, saying eggs could be crushed by the vehicles.

https://www.bbc.com/news/technology-57148214

C.1.6 UK universities online till fall

A number of UK universities are preparing to keep lectures online into the autumn term.

It raises the prospect of Covid disrupting another academic year - and will prompt more questions about fee refunds.

Students have called plans for another term of online lectures "unacceptable".

"Online teaching is in no way a substitute for in-person learning," says a petition launched by University of Leeds students.

About half of students in England have only been able to return to face-to-face teaching this week, not long before the term ends - having been taught online since Christmas. 'Pre-recorded video'

But a growing number of universities seem to be anticipating carrying on with a mix of online and in-person teaching into the autumn term.

The University of Liverpool says it wants as "much face-to-face teaching as possible", but is expecting a blend of online and in-person.

https://www.bbc.com/news/education-57150071

C.1.7 Charlie bit my finger sold

"Ouch, Charlie bit me! That really hurt, Charlie!"

If you were online in 2007, you're likely one of the 880 million people who have seen the iconic video of Charlie biting his brother Harry's finger.

In the days when viral videos were few and far between, this one was etched into everyone's memories.

Now, the Davis-Carr family are removing their video from YouTube and auctioning it as an NFT, or non-fungible token. line

The video was uploaded it to YouTube by Harry and Charlie's dad, Howard, in 2007, because he couldn't email it to their godparents in America.

The family website says the clip was filmed as "a part of catching random moments as the boys were growing up", and that it "unintentionally went viral".

What are NFTs and why are some worth millions? Watch: 'Memes should be archived in a museum' Are NFTs a new opportunity for digital artists?

The boys, who are now 17 and 15, are "soon entering adulthood" so it's the right time to "embrace the next iteration of the internet", the site adds.

"This is not the end of the beloved video, but rather a new beginning."

https://www.bbc.com/news/newsbeat-57168631

C.1.8 Amazon buying MGM

Amazon is reportedly in talks to buy the historic MGM Studios for $9bn (Â£6.35bn).

MGM is one of Hollywood's most famous studios, with its Leo the Lion logo and an almost century-long history.

The sale would give the technology giant's Prime streaming service access to a vast back catalogue of iconic content.

Amazon and MGM Studios told the BBC that they did not comment on rumours or speculation.

The reports come just hours after telecoms giant AT&T agreed to combine its WarnerMedia unit with Discovery in a deal to create a new streaming giant.

MGM Holdings, the parent company of MGM Studios, has reportedly been exploring a sale since the end of last year, according to media reports.

The purchase by Amazon of MGM Studios would mark a major step for its Prime streaming service.

MGM Studios has a huge catalogue of films and television shows covering the last ten decades, through the Golden Age of Hollywood to the present day.

In more recent times it has produced the James Bond movie franchise and The Handmaid's Tale TV series.

https://www.bbc.com/news/business-57153680

C.1.9 Should encryption be curbed

For nine years, Chris Hughes has fought a battle very few people ever see.

He oversees a team of 21 analysts in Cambridge who locate, identify and remove child sexual abuse material (CSAM) from the internet.

The Internet Watch Foundation (IWF) is funded by the global tech industry.

It manually reviews online reports of suspected criminal content sent in by the public. Mr Hughes sees upsetting material every day.

When content is verified, analysts create unique "digital fingerprints" of each photo or video, then send it to law enforcement and tech firms. They also search for material online.

Occasionally, there are harrowing situations racing to track down victims from live streaming video.

Reports jumped during the pandemic, he says: "Over the recent May bank holiday weekend, we had more than 2,000 reports."

https://www.bbc.com/news/business-57050689

C.1.10 Self driving car blocked in Arizona

A self-driving taxi has blocked a road in Arizona after becoming confused by a lane closed off with traffic cones.

The Waymo vehicle repeatedly drove away from roadside assistance, dispatched within minutes of the car becoming stuck.

Passenger Joel Johnson documented the experience on his YouTube channel.

The Alphabet-owned company said it was an "unusual situation" and the taxi had operated safely throughout the journey.

Waymo is the first fully self-driving taxi service legally allowed to operate.

For now, it is available in the East Valley district of Phoenix only.

https://www.bbc.com/news/technology-57144755

C.1.11 Firefox previews site isolation

Mozilla on Tuesday announced that a years-long effort to harden Firefox's defenses can now be previewed in the browser's Nightly and Beta builds.

Debuting as "Project Fission" in February 2019, the project was also linked to the more descriptive "site isolation," a defensive technology in which a browser devotes separate processes to each domain or even each website, and in some cases, assigns different processes to site components, such as iframes, so they are rendered separately from the process handling the overall site.

The idea is to isolate malicious sites and components - and the attack code they harbor - so one site cannot exploit an unknown vulnerability or one still unpatched, then plunder the browser, or the device, or a device's memory of crucial information. That information could include authentication credentials, confidential data, and encryption keys.

https://www.computerworld.com/article/3619064/firefox-previews-site-isolation-tech-in-move-to-catch-up-to-chrome.html

C.1.12 VMware remote work security

Providing secure access to vital applications has been a key challenge for businesses forced to adapt to remote working during the pandemic. And with many businesses set to continue to support a distributed workforce even after offices reopen, it will remain a priority for IT for some time.

With this in mind, VMware has unveiled a suite of security and endpoint management tools to support remote workers. VMware Anywhere Workspace, announced on Tuesday, combines VMware's Workspace One, a "digital workspace platform" that delivers applications across a range of devices, with its Carbon Black Cloud endpoint security tools and SASE, which provides secure network access for distributed teams.

"By combining these three things we can deliver value to the stakeholders that include employees, the CIO, CISO, lines of business and HR," said Shankar Iyer, SVP and general manager, end user computing at VMware. "This results in highly engaged employees, a broader and more effective security model, reduced cost and overhead."

https://www.computerworld.com/article/3615593/vmware-targets-remote-work-security-with-anywhere-workspace.html

C.2 Experiment 2

C.2.1 Amazon

Amazon has sealed an $8.45 billion deal to buy MGM, the company that owns the iconic Hollywood studio known for releasing movies in the James Bond and Rocky franchises. The deal sets a course to amp up Amazon Prime Video with new programming mined from MGM's long history and to bolster Amazon's existing original production arm, Amazon Studios.

Amazon said MGM's goldmine is the intellectual property that it can leverage for making new content – the beloved franchises that Amazon can now tap into to make new material.

"The real financial value behind this deal is the treasure trove of IP in the deep catalog that we plan to reimagine and develop together with MGM's talented team," Mike Hopkins, Amazon's senior vice president of Prime Video and Amazon Studios, said in a release. "It's very exciting and provides so many opportunities for high-quality storytelling."

https://www.cnet.com/news/amazon-buys-mgm-setting-prime-video-up-for-a-james-bond-rocky-infusion/

C.2.2 Android Malware

Holy floppin' hellfire, Henry! Have you heard? A terrifying new form of Android malware is running amok - stealing passwords, emptying bank accounts, and drinking all the grape soda from the refrigerators of unsuspecting Android phone owners.

We should all be quivering in our rainboots, according to almost all the information I've read on these here internets. Numerous adjective-filled news stories have warned me that the "scary new Android malware" is "spreading quickly," targeting "millions" (millions!) of users, and occasionally even "kicking people square in the groin." (All right, so I made that last part up. But you get the idea.)

BUT WAIT! It gets worse: The malware, known as FluBot (because it wouldn't be Android malware if it didn't have an annoyingly cutesy name), works by showing up on your phone, gaining access to all of your most sensitive data, and then sending your deepest secrets to hooligans who are preemptively cackling over your unavoidable misfortune.

It's enough to make you want to toss your Android phone into the nearest quarry and go into permanent hiding. I get it - who wouldn't react that way? Before you start searching for the nearest bunker, though, there's something you should know about this menacing Android malware. And it's something that, if we're being fully honest, applies to the vast majority of fear-inducing Android security stories we see out in the wild.

Ready? This Android malware should be incredibly scary for you - if, that is, you're a complete and total nitwit.

https://www.computerworld.com/article/3616703/android-security-warning.html

C.2.3 Apple Watch accessibility

Any enterprise eager to meet accessibility and diversity targets now has additional reasons to consider Apple's technologies, with Assistive Touch for Apple Watch hinting at a gesture-based future for wearable tech. Accessibility for the rest of us?

Apple made a series of announcements to mark Global Accessibility Awareness Day, which is today. New accessible user interface (UI) enhancements included support for third-party, eye-tracking hardware to control iPads and a very interesting use of machine vision intelligence so your device can identify objects within images when using voice to control the device.

But it's Assistive Touch for Apple Watch that feels most like watching Minority Report, because it introduces new gesture controls. These use built-in motion sensors inside the watch, including the gyroscope, accelerometer, optical heart rate sensor, and on-device machine learning to detect subtle differences in muscle movement and tendon activity.

These gestures are then translated into actions, so it's possible to answer a call by clenching your hand as your raise your wrist, or to scroll an on-page app interface by moving your hand.

https://www.computerworld.com/article/3619889/accessibility-takes-a-magic-leap-with-apple-watch-gesture-control.html

C.2.4 Bitcoin

Iran has announced a four-month ban on the energy-consuming mining of cryptocurrencies such as Bitcoin after cities suffered unplanned blackouts.

President Hassan Rouhani told a cabinet meeting the main cause of the blackouts was a drought that had affected hydro-electric power generation.

But he said cryptocurrency mining, 85% of which is unlicensed, was draining more than 2GW from the grid each day.

An estimated 4.5% of all Bitcoin mining takes place in Iran.

According to analytics firm Elliptic, the activity allows the country to bypass sanctions and earn hundreds of millions of dollars in crypto-assets that can be used to purchase imports.

Bitcoin consumes 'more electricity than Argentina'

Iran's banks were cut off from the global financial system and its oil exports plummeted, depriving it of a major source of hard currency and revenue, as a result of sanctions reinstated by the US in 2018 when then President Donald Trump abandoned a landmark nuclear deal.

Bitcoin operates on the blockchain, a digital ledger of transactions. Miners audit Bitcoin transactions in exchange for an opportunity to acquire the digital currency. It requires enormous computing power, which in turn uses huge amounts of electricity.

https://www.bbc.com/news/world-middle-east-57260829

C.2.5 Friends

When Matt LeBlanc and Matthew Perry plop down in side-by-side leather lounge chairs in Friends: The Reunion on HBO Max, it is, for a moment, as if no time has passed since their characters reclined in front of their cherished TV set all those years ago.

Yet the actors have lived lifetimes since a young Joey Tribbiani and Chandler Bing shared a New York bachelor pad on the long-running NBC comedy. And in the case of the 51-year-old Perry, who's battled addiction and spent three months in the hospital following gastrointestinal surgery, life hasn't always been funny.

"Aww, Matty, it's good to see you, man," Perry tells the affable LeBlanc, now a 53-year-old teddy bear of a guy who delivers lingering hugs to his former cast mates.

There's a genuine warmth to the exchange between the two actors, and as an old episode flashes back to them in their 20s, sitting in barcaloungers in the exact same spot, it's hard not to feel a bit melancholy. Now they're two middle-aged guys with gray hair and more lived experience, together again and looking back. It's a simple moment, tinged with a poignancy that permeates the whole special.

The highly anticipated reunion, also dubbed The One Where They Get Back Together, reunites the six lead actors on the show's original soundstage at the Warner Bros. Studio lot in Burbank, California. It's the first time LeBlanc, Perry, Jennifer Aniston, Courtney Cox, Lisa Kudrow and David Schwimmer have been together in the same room since the finale aired in 2004.

https://www.cnet.com/news/friends-the-reunion-on-hbo-max-review-drags-in-spots-but-is-mostly-a-poignant-homecoming/

C.2.6 Instagram

Instagram is offering its users the option to hide the number of likes they receive on posts on the app.

The aim is to "depressurize people's experience" on the platform, the social media giant said.

Users with the feature enabled will now see the username of a follower who has liked the post, "and others", instead of a number.

The tool has been tested in several countries since 2019, but it is now being rolled out globally.

"This has taken longer than I had hoped, but I am pretty excited about... giving people more control over the experience," Instagram's boss Adam Mosseri told the BBC.

In its testing and research, Instagram said that removing likes had little impact on behaviour or wellbeing - after concerns that using the platform could be linked to insecurity and poor mental health.

Despite this, Mr Mosseri said Instagram - which is owned by Facebook - introduced the feature to make "people feel good about the time they spend" on the platform.

"I do think there's more to do in this space," he added. "The more we can give people the ability to shape Instagram and Facebook into what's good for them, the better."

https://www.bbc.com/news/technology-57254488

C.2.7 Microsoft Enterprise

Microsoft last week launched a public preview of the APIs (application programming interfaces) that IT admins can call on to control Windows Update for Business Deployment Service, the company's latest effort to push commercial customers to adopt cloud-only servicing for Windows 10.

"With today's public preview release, you can use the Windows Update for Business deployment service directly through the Microsoft Graph API and associated SDKs, as well as Azure PowerShell," David Mebane, principal program manager lead with the Windows servicing group, said in an April 28 post.

Although Microsoft trumpeted WUfB Deployment Service at its Ignite developers conference last month, Friday was the unveiling of any actual functionality. Nor were the APIs made available last week the story's end, as Microsoft will continue to expand on the preview's functionality over an as-yet-not-nailed-down timeline.

Out the gate, IT administrators can:

Approve and schedule feature upgrade deployments such as last fall's 20H2. Admins can also instruct the service not to distribute an upgrade, useful for skipping one that's available.

Stage deployments over a period of time by defining delivery date, desired feature upgrade, and number of machines affected.

Sidestep existing policies to immediately deploy a security update, say, when Microsoft issues an emergency fix for a vulnerability currently being widely exploited by attackers.

Customers with licenses to a number of Microsoft's subscription plans can use the APIs immediately, according to Mebane, including:

Windows 10 Enterprise E3 or E5, or Windows 10 Education A3 or A5

Windows Virtual Desktop Access E3 or E5

Microsoft 365 Business Premium (a subscription that supports Windows 10 Pro)

https://www.computerworld.com/article/3617301/microsoft-previews-new-windows-servicing-apis-for-enterprises.html

C.2.8 Royal Mail

Royal Mail has announced its first delivery office to have an all-electric fleet of collection and delivery vehicles.

Bristol East Central Delivery Office's 23 diesel vehicles have been replaced by fully-electric ones.

Royal Mail said Bristol was selected because of its plans to introduce a Clean Air Zone (CAZ) later this year.

Chief executive Simon Thompson described the move as a "really positive step".

Six electric charging posts have also been installed on the site, with electricity for powering the office and charging the vehicles coming from renewable sources.

Mr Thompson said the move would allow them to assess the impact of the changes on customers and staff, and consider changes to other delivery offices.

"It's clear to me that customers increasingly want less environmentally impacting deliveries," he said.

"We are delighted to transform Bristol East Central into the very first Royal Mail 'all-electric' delivery office."

The electric vans have a bigger load space than the vehicles they have replaced, giving them additional capacity to deal with growing parcel volumes, and have lower maintenance requirements.

https://www.bbc.com/news/uk-england-bristol-57256872

C.2.9 Russia Facebook

Russia has been the main source of disinformation on Facebook since 2017, the social network said in a report Wednesday. The company uncovered disinformation campaigns in more than 50 countries in that period and shut down 150 networks of fake accounts.

Aside from Russia, the top sources of fake news have been Iran, Myanmar, the US and Ukraine. The US, Ukraine, Britain, Libya and Sudan have been the most frequent targets.

Read more: Permanently delete your Facebook account, loose ends and all

"Influence operations are not new, but over the past several years they have burst into global public consciousness," Facebook wrote in the report. "These campaigns attempt to undermine trust in civic institutions and corrupt public debate by exploiting the same digital tools that have diversified the online public square and empowered critical discussions from Me Too to the Black Lives Matter movements."

The 2016 US presidential election was a "watershed moment" for disinformation, the report noted, but the techniques used then "are now harder to pull off, more expensive and less likely to succeed." However, the people responsible for disinformation have found more subtle approaches like co-opting legitimate Facebook users.

https://www.cnet.com/news/russia-remains-the-biggest-source-of-disinformation-facebook-says/

C.2.10 Whatsapp

WhatsApp is suing the Indian government over new digital rules that will force the messaging service to violate privacy protections.

It said rules that require tracing the origin of chats were the equivalent of keeping a "fingerprint of every single message sent on the service".

In February, the government introduced new guidelines to regulate content on social media and streaming platforms.

India is WhatsApp's largest market with about 400 million users.

The government's rules for social media said that messaging platforms would need to make provisions for the "identification of the first originator of the information".

Whatsapp filed a plea in the high court in Delhi asking it to declare the new rule unconstitutional.

In a statement, a WhatsApp spokesperson said that the rules "would break end-to-end encryption and fundamentally undermine people's right to privacy".

"We have consistently joined civil society and experts around the world in opposing requirements that would violate the privacy of our users. In the meantime, we will also continue to engage with the government of India on practical solutions aimed at keeping people safe, including responding to valid legal requests for the information available to us," WhatsApp said.

According to the messaging service, traceability of texts would force private companies to collect and store billions of messages sent each day for the sole purpose of turning it over to law enforcement agencies.

https://www.bbc.com/news/world-asia-india-57251612

C.2.11 Window update

Microsoft CEO Satya Nadella said his company is planning "one of the most significant updates of Windows of the past decade," its software that powers more than 1.3 billion people's devices. Although he didn't offer details, Nadella said Microsoft plans to unveil the new version "very soon."

"I've been using it over the past several months and I'm incredibly excited about the next generation of Windows," he said.

We don't know much about the next generation of Windows software, other than Nadella's earlier promise that the company would "double down" on Windows and PCs. Rumors about the new version, code-named Cobalt, point to updates for the user interface (known as Sun Valley), meant to "reinvigorate" and modernize its look. The last time Microsoft meaningfully changed its look was with Windows 10, which was first released in 2015, following Windows 8.1. Microsoft hasn't said when its new Windows update will be released, but CNET sister site ZDNet said it's targeted for the second half of this year.

https://www.cnet.com/news/microsoft-ceo-satya-nadella-teases-next-version-of-windows-very-soon/

C.3 Main Experiment Texts

C.3.1 Disney

Introduction

Walter Elias Disney (December 5, 1901 – December 15, 1966) was an American entrepreneur, animator, writer, voice actor, and film producer. A pioneer of the American animation industry, he introduced several developments in the production of cartoons. As a film producer, Disney holds the record for most Academy Awards earned by an individual, having won 22 Oscars from 59 nominations. He was presented with two Golden Globe Special Achievement Awards and an Emmy Award, among other honors. Several of his films are included in the National Film Registry by the Library of Congress.

Born in Chicago in 1901, Disney developed an early interest in drawing. He took art classes as a boy and got a job as a commercial illustrator at the age of 18. He moved to California in the early 1920s and set up the Disney Brothers Studio with his brother Roy. With Ub Iwerks, Walt developed the character Mickey Mouse in 1928, his first highly popular success; he also provided the voice for his creation in the early years. As the studio grew, Disney became more adventurous, introducing synchronized sound, full-color three-strip Technicolor, feature-length cartoons and technical developments in cameras. The results, seen in features such as Snow White and the Seven Dwarfs (1937), Pinocchio, Fantasia (both 1940), Dumbo (1941), and Bambi (1942), furthered the development of animated film. New animated and live-action films followed after World War II, including the critically successful Cinderella (1950) and Mary Poppins (1964), the latter of which received five Academy Awards.

In the 1950s, Disney expanded into the amusement park industry, and in July 1955 he opened Disneyland in Anaheim, California. To fund the project he diversified into television programs, such as Walt Disney's Disneyland and The Mickey Mouse Club; he was also involved in planning the 1959 Moscow Fair, the 1960 Winter Olympics, and the 1964 New York World's Fair. In 1965, he began development of another theme park, Disney World, the heart of which was to be a new type of city, the "Experimental Prototype Community of Tomorrow" (EPCOT). Disney was a heavy smoker throughout his life and died of lung cancer in December 1966 before either the park or the EPCOT project were completed.

Disney was a shy, self-deprecating and insecure man in private but adopted a warm and outgoing public persona. He had high standards and high expectations of those with whom he worked. Although there have been accusations that he was racist or anti-Semitic, they have been contradicted by many who knew him. His reputation changed in the years after his death, from a purveyor of homely patriotic values to a representative of American imperialism. He nevertheless remains an important figure in the history of animation and in the cultural history of the United States, where he is considered a national cultural icon. His film work continues to be shown and adapted; his namesake studio and company maintains high standards in its production of popular entertainment, and the Disney amusement parks have grown in size and number to attract visitors in several countries.

Early life: 1901–1920

Walt Disney was born on December 5, 1901, at 1249 Tripp Avenue, in Chicago's

Hermosa neighborhood. He was the fourth son of Elias Disney—born in the Province of Canada, to Irish parents—and Flora (née Call), an American of German and English descent. Aside from Walt, Elias and Flora's sons were Herbert, Raymond and Roy; the couple had a fifth child, Ruth, in December 1903. In 1906, when Disney was four, the family moved to a farm in Marceline, Missouri, where his uncle Robert had just purchased land. In Marceline, Disney developed his interest in drawing when he was paid to draw the horse of a retired neighborhood doctor. Elias was a subscriber to the Appeal to Reason newspaper, and Disney practiced drawing by copying the front-page cartoons of Ryan Walker. Disney also began to develop an ability to work with watercolors and crayons. He lived near the Atchison, Topeka and Santa Fe Railway line and became enamored with trains. He and his younger sister Ruth started school at the same time at the Park School in Marceline in late 1909.

In 1911, the Disneys moved to Kansas City, Missouri. There, Disney attended the Benton Grammar School, where he met fellow-student Walter Pfeiffer, who came from a family of theatre fans and introduced Disney to the world of vaudeville and motion pictures. Before long, he was spending more time at the Pfeiffers' house than at home. Elias had purchased a newspaper delivery route for The Kansas City Star and Kansas City Times. Disney and his brother Roy woke up at 4:30 every morning to deliver the Times before school and repeated the round for the evening Star after school. The schedule was exhausting, and Disney often received poor grades after falling asleep in class, but he continued his paper route for more than six years. He attended Saturday courses at the Kansas City Art Institute and also took a correspondence course in cartooning.

In 1917, Elias bought stock in a Chicago jelly producer, the O-Zell Company, and moved back to the city with his family. Disney enrolled at McKinley High School and became the cartoonist of the school newspaper, drawing patriotic pictures about World War I; he also took night courses at the Chicago Academy of Fine Arts. In mid-1918, Disney attempted to join the United States Army to fight against the Germans, but he was rejected for being too young. After forging the date of birth on his birth certificate, he joined the Red Cross in September 1918 as an ambulance driver. He was shipped to France but arrived in November, after the armistice. He drew cartoons on the side of his ambulance for decoration and had some of his work published in the army newspaper Stars and Stripes. Disney returned to Kansas City in October 1919, where he worked as an apprentice artist at the Pesmen-Rubin Commercial Art Studio. There, he drew commercial illustrations for advertising, theater programs and catalogs. He also befriended fellow artist Ub Iwerks.

Early career: 1920–1928

In January 1920, as Pesmen-Rubin's revenue declined after Christmas, Disney, aged 18, and Iwerks were laid off. They started their own business, the short-lived Iwerks-Disney Commercial Artists. Failing to attract many customers, Disney and Iwerks agreed that Disney should leave temporarily to earn money at the Kansas City Film Ad Company, run by A. V. Cauger; the following month Iwerks, who was not able to run their business alone, also joined. The company produced commercials using the cutout animation technique. Disney became interested in animation, although he preferred drawn cartoons such as Mutt and Jeff and Koko the Clown. With the assistance of a borrowed book on animation and

a camera, he began experimenting at home. He came to the conclusion that cel animation was more promising than the cutout method. Unable to persuade Cauger to try cel animation at the company, Disney opened a new business with a co-worker from the Film Ad Co, Fred Harman. Their main client was the local Newman Theater, and the short cartoons they produced were sold as "Newman's Laugh-O-Grams". Disney studied Paul Terry's Aesop's Fables as a model, and the first six "Laugh-O-Grams" were modernized fairy tales.

In May 1921, the success of the "Laugh-O-Grams" led to the establishment of Laugh-O-Gram Studio, for which he hired more animators, including Fred Harman's brother Hugh, Rudolf Ising and Iwerks. The Laugh-O-Grams cartoons did not provide enough income to keep the company solvent, so Disney started production of Alice's Wonderland—based on Alice's Adventures in Wonderland—which combined live action with animation; he cast Virginia Davis in the title role. The result, a 12-and-a-half-minute, one-reel film, was completed too late to save Laugh-O-Gram Studio, which went into bankruptcy in 1923.

Disney moved to Hollywood in July 1923 at 21 years old. Although New York was the center of the cartoon industry, he was attracted to Los Angeles because his brother Roy was convalescing from tuberculosis there, and he hoped to become a live-action film director. Disney's efforts to sell Alice's Wonderland were in vain until he heard from New York film distributor Margaret J. Winkler. She was losing the rights to both the Out of the Inkwell and Felix the Cat cartoons, and needed a new series. In October, they signed a contract for six Alice comedies, with an option for two further series of six episodes each. Disney and his brother Roy formed the Disney Brothers Studio—which later became The Walt Disney Company—to produce the films; they persuaded Davis and her family to relocate to Hollywood to continue production, with Davis on contract at $100 a month. In July 1924, Disney also hired Iwerks, persuading him to relocate to Hollywood from Kansas City.

Early in 1925, Disney hired an ink artist, Lillian Bounds. They married in July of that year, at her brother's house in her hometown of Lewiston, Idaho. The marriage was generally happy, according to Lillian, although according to Disney's biographer Neal Gabler she did not "accept Walt's decisions meekly or his status unquestionably, and she admitted that he was always telling people 'how henpecked he is'." Lillian had little interest in films or the Hollywood social scene and she was, in the words of the historian Steven Watts, "content with household management and providing support for her husband". Their marriage produced two daughters, Diane (born December 1933) and Sharon (adopted in December 1936, born six weeks previously). Within the family, neither Disney nor his wife hid the fact Sharon had been adopted, although they became annoyed if people outside the family raised the point. The Disneys were careful to keep their daughters out of the public eye as much as possible, particularly in the light of the Lindbergh kidnapping; Disney took steps to ensure his daughters were not photographed by the press.

By 1926 Winkler's role in the distribution of the Alice series had been handed over to her husband, the film producer Charles Mintz, although the relationship between him and Disney was sometimes strained. The series ran until July 1927, by which time Disney had begun to tire of it and wanted to move away from the mixed format to all animation. After Mintz requested new material to distribute through Universal Pictures, Disney and Iwerks created Oswald the Lucky Rabbit, a character Disney wanted to be "peppy, alert, saucy and venturesome, keeping him

also neat and trim".

In February 1928, Disney hoped to negotiate a larger fee for producing the Oswald series, but found Mintz wanting to reduce the payments. Mintz had also persuaded many of the artists involved to work directly for him, including Harman, Ising, Carman Maxwell and Friz Freleng. Disney also found out that Universal owned the intellectual property rights to Oswald. Mintz threatened to start his own studio and produce the series himself if Disney refused to accept the reductions. Disney declined Mintz's ultimatum and lost most of his animation staff, except Iwerks, who chose to remain with him.

Creation of Mickey Mouse to the first Academy Awards: 1928–1933

To replace Oswald, Disney and Iwerks developed Mickey Mouse, possibly inspired by a pet mouse that Disney had adopted while working in his Laugh-O-Gram studio, although the origins of the character are unclear. Disney's original choice of name was Mortimer Mouse, but Lillian thought it too pompous, and suggested Mickey instead. Iwerks revised Disney's provisional sketches to make the character easier to animate. Disney, who had begun to distance himself from the animation process, provided Mickey's voice until 1947. In the words of one Disney employee, "Ub designed Mickey's physical appearance, but Walt gave him his soul."

Mickey Mouse first appeared in May 1928 as a single test screening of the short Plane Crazy, but it, and the second feature, The Gallopin' Gaucho, failed to find a distributor. Following the 1927 sensation The Jazz Singer, Disney used synchronized sound on the third short, Steamboat Willie, to create the first post-produced sound cartoon. After the animation was complete, Disney signed a contract with the former executive of Universal Pictures, Pat Powers, to use the "Powers Cinephone" recording system; Cinephone became the new distributor for Disney's early sound cartoons, which soon became popular.

To improve the quality of the music, Disney hired the professional composer and arranger Carl Stalling, on whose suggestion the Silly Symphony series was developed, providing stories through the use of music; the first in the series, The Skeleton Dance (1929), was drawn and animated entirely by Iwerks. Also hired at this time were several local artists, some of whom stayed with the company as core animators; the group later became known as the Nine Old Men. Both the Mickey Mouse and Silly Symphonies series were successful, but Disney and his brother felt they were not receiving their rightful share of profits from Powers. In 1930, Disney tried to trim costs from the process by urging Iwerks to abandon the practice of animating every separate cel in favor of the more efficient technique of drawing key poses and letting lower-paid assistants sketch the inbetween poses. Disney asked Powers for an increase in payments for the cartoons. Powers refused and signed Iwerks to work for him; Stalling resigned shortly afterwards, thinking that without Iwerks, the Disney Studio would close. Disney had a nervous breakdown in October 1931—which he blamed on the machinations of Powers and his own overwork—so he and Lillian took an extended holiday to Cuba and a cruise to Panama to recover.

With the loss of Powers as distributor, Disney studios signed a contract with Columbia Pictures to distribute the Mickey Mouse cartoons, which became

increasingly popular, including internationally. Disney, always keen to embrace new technology, filmed Flowers and Trees (1932) in full-color three-strip Technicolor; he was also able to negotiate a deal giving him the sole right to use the three-strip process until August 31, 1935. All subsequent Silly Symphony cartoons were in color. Flowers and Trees was popular with audiences and won the Academy Award for best Short Subject (Cartoon) at the 1932 ceremony. Disney had been nominated for another film in that category, Mickey's Orphans, and received an Honorary Award "for the creation of Mickey Mouse".

In 1933, Disney produced The Three Little Pigs, a film described by the media historian Adrian Danks as "the most successful short animation of all time". The film won Disney another Academy Award in the Short Subject (Cartoon) category. The film's success led to a further increase in the studio's staff, which numbered nearly 200 by the end of the year. Disney realized the importance of telling emotionally gripping stories that would interest the audience, and he invested in a "story department" separate from the animators, with storyboard artists who would detail the plots of Disney's films.

Golden age of animation: 1934–1941

By 1934, Disney had become dissatisfied with producing formulaic cartoon shorts, and believed a feature-length cartoon would be more profitable. The studio began the four-year production of Snow White and the Seven Dwarfs, based on the fairy tale. When news leaked out about the project, many in the film industry predicted it would bankrupt the company; industry insiders nicknamed it "Disney's Folly". The film, which was the first animated feature made in full color and sound, cost $1.5 million to produce—three times over budget. To ensure the animation was as realistic as possible, Disney sent his animators on courses at the Chouinard Art Institute; he brought animals into the studio and hired actors so that the animators could study realistic movement. To portray the changing perspective of the background as a camera moved through a scene, Disney's animators developed a multiplane camera which allowed drawings on pieces of glass to be set at various distances from the camera, creating an illusion of depth. The glass could be moved to create the impression of a camera passing through the scene. The first work created on the camera—a Silly Symphony called The Old Mill (1937)—won the Academy Award for Animated Short Film because of its impressive visual power. Although Snow White had been largely finished by the time the multiplane camera had been completed, Disney ordered some scenes be re-drawn to use the new effects.

Snow White premiered in December 1937 to high praise from critics and audiences. The film became the most successful motion picture of 1938 and by May 1939 its total gross of $6.5 million made it the most successful sound film made to that date. Disney won another Honorary Academy Award, which consisted of one full-sized and seven miniature Oscar statuettes. The success of Snow White heralded one of the most productive eras for the studio; the Walt Disney Family Museum calls the following years "the 'Golden Age of Animation' ". With work on Snow White finished, the studio began producing Pinocchio in early 1938 and Fantasia in November of the same year. Both films were released in 1940, and neither performed well at the box office—partly because revenues from Europe had dropped following the start of World War II in 1939. The studio made a loss on both pictures and was deeply in debt by the end of February 1941.

In response to the financial crisis, Disney and his brother Roy started the company's first public stock offering in 1940, and implemented heavy salary cuts. The latter measure, and Disney's sometimes high-handed and insensitive manner of dealing with staff, led to a 1941 animators' strike which lasted five weeks. While a federal mediator from the National Labor Relations Board negotiated with the two sides, Disney accepted an offer from the Office of the Coordinator of Inter-American Affairs to make a goodwill trip to South America, ensuring he was absent during a resolution he knew would be unfavorable to the studio. As a result of the strike—and the financial state of the company—several animators left the studio, and Disney's relationship with other members of staff was permanently strained as a result. The strike temporarily interrupted the studio's next production, Dumbo (1941), which Disney produced in a simple and inexpensive manner; the film received a positive reaction from audiences and critics alike.

World War II and beyond: 1941–1950

Shortly after the release of Dumbo in October 1941, the U.S. entered World War II. Disney formed the Walt Disney Training Films Unit within the company to produce instruction films for the military such as Four Methods of Flush Riveting and Aircraft Production Methods. Disney also met with Henry Morgenthau Jr., the Secretary of the Treasury, and agreed to produce short Donald Duck cartoons to promote war bonds. Disney also produced several propaganda productions, including shorts such as Der Fuehrer's Face—which won an Academy Award—and the 1943 feature film Victory Through Air Power.

The military films generated only enough revenue to cover costs, and the feature film Bambi—which had been in production since 1937—underperformed on its release in April 1942, and lost $200,000 at the box office. On top of the low earnings from Pinocchio and Fantasia, the company had debts of $4 million with the Bank of America in 1944. At a meeting with Bank of America executives to discuss the future of the company, the bank's chairman and founder, Amadeo Giannini, told his executives, "I've been watching the Disneys' pictures quite closely because I knew we were lending them money far above the financial risk. ... They're good this year, they're good next year, and they're good the year after. ... You have to relax and give them time to market their product." Disney's production of short films decreased in the late 1940s, coinciding with increasing competition in the animation market from Warner Bros. and Metro-Goldwyn-Mayer. Roy Disney, for financial reasons, suggested more combined animation and live-action productions. In 1948, Disney initiated a series of popular live-action nature films, titled True-Life Adventures, with Seal Island the first; the film won the Academy Award in the Best Short Subject (Two-Reel) category.

Disney grew more politically conservative as he got older. A Democratic Party supporter until the 1940 presidential election, when he switched allegiance to the Republican Party, he became a generous donor to Thomas E. Dewey's 1944 bid for the presidency. In 1946, he was a founding member of the Motion Picture Alliance for the Preservation of American Ideals, an organization who stated they "believ in, and like, the American Way of Life ... we find ourselves in sharp revolt against a rising tide of Communism, Fascism and kindred beliefs, that seek by subversive means to undermine and change this way of life". In

1947, during the Second Red Scare, Disney testified before the House Un-American Activities Committee (HUAC), where he branded Herbert Sorrell, David Hilberman and William Pomerance, former animators and labor union organizers, as communist agitators; Disney stated that the 1941 strike led by them was part of an organized communist effort to gain influence in Hollywood. It was alleged by The New York Times in 1993 that Disney had been passing secret information to the FBI from 1940 until his death in 1966. In return for this information, J. Edgar Hoover allowed Disney to film in FBI headquarters in Washington. Disney was made a "full Special Agent in Charge Contact" in 1954.

In 1949, Disney and his family moved to a new home in the Holmby Hills district of Los Angeles. With the help of his friends Ward and Betty Kimball, who already had their own backyard railroad, Disney developed blueprints and immediately set to work on creating a miniature live steam railroad for his backyard. The name of the railroad, Carolwood Pacific Railroad, came from his home's location on Carolwood Drive. The miniature working steam locomotive was built by Disney Studios engineer Roger E. Broggie, and Disney named it Lilly Belle after his wife; after three years Disney ordered it into storage due to a series of accidents involving his guests.

Theme parks, television and other interests: 1950–1966

In early 1950, Disney produced Cinderella, his studio's first animated feature in eight years. It was popular with critics and theater audiences. Costing $2.2 million to produce, it earned nearly $8 million in its first year. Disney was less involved than he had been with previous pictures because of his involvement in his first entirely live-action feature, Treasure Island (1950), which was shot in Britain, as was The Story of Robin Hood and His Merrie Men (1952). Other all-live-action features followed, many of which had patriotic themes. He continued to produce full-length animated features too, including Alice in Wonderland (1951, which he could finally create, having plans to create it going back to the beginning of his career) and Peter Pan (1953). From the early to mid-1950s, Disney began to devote less attention to the animation department, entrusting most of its operations to his key animators, the Nine Old Men, although he was always present at story meetings. Instead, he started concentrating on other ventures.

For several years Disney had been considering building a theme park. When he visited Griffith Park in Los Angeles with his daughters, he wanted to be in a clean, unspoiled park, where both children and their parents could have fun. The story goes that he came up with the idea for Disneyland while sitting on a bench in Griffith Park, watching his children riding the marry-go-round. The bench he set at and the marry-go-round still exist to this day and both have become a favorite location to visit for both Disney and Disneypark fans around the world. He visited the Tivoli Gardens in Copenhagen, Denmark, and was heavily influenced by the cleanliness and layout of the park. For a long time people believed Walt also visited the Efteling to get inspiration for Disneyland, but this story has since been debunked. Former PR-employee Reinoud van Assendelft de Coningh said about this: "As a PR-employee, I were responsible for the story of Walt Disney visiting the Efteling. I once told a couple of journalists that it could be possible that Walt Disney once visited the Efteling. It was known that for his plans to build a amusement park in the US, he came to Europe to get inspiration.

He has been to Denmark, that is for sure, but nobody knows if he actually visited the Efteling. There are no whitnesses, nor pictures. After I told my story to the journalists, I sad in an airplan and read in the paper of the aircompany that Walt Disney has visited the Efteling for inspiration. The 'maybe' was scraped from the story. From there on the story went on the lead its own live. Even the vice-president of Disney, Ted Crowell, believed the story to be true. He said at the Applause Award in 1992 that it is not weird that the Efteling received the highest decoration, because it had to be a fantastic park because Walt went there to get inspiration for his own parks"

In March 1952 Walt received zoning permission to build a theme park in Burbank, near the Disney studios. This site proved too small, and a larger plot in Anaheim, 35 miles (56 km) south of the studio, was purchased. To distance the project from the studio—which might attract the criticism of shareholders—Disney formed WED Enterprises (now Walt Disney Imagineering) and used his own money to fund a group of designers and animators to work on the plans; those involved became known as "Imagineers". The emloyees at WED were encouraged to come up with inovative ideas and let there imagination run free. After obtaining bank funding he invited other stockholders, American Broadcasting-Paramount Theatres—part of American Broadcasting Company (ABC)—and Western Printing and Lithographing Company. In mid-1954, Disney sent his Imagineers to every amusement park in the U.S. to analyze what worked and what pitfalls or problems there were in the various locations and incorporated their findings into his design. Construction work started in July 1954, and Disneyland opened in July 1955; the opening ceremony was broadcast on ABC, which reached 70 million viewers. The park was designed as a series of themed lands, linked by the central Main Street, U.S.A.—a replica of the main street in his hometown of Marceline. The connected themed areas were Adventureland, Frontierland, Fantasyland and Tomorrowland. The park also contained the narrow gauge Disneyland Railroad that linked the lands; around the outside of the park was a high berm to separate the park from the outside world. An editorial in The New York Times considered that Disney had "tastefully combined some of the pleasant things of yesterday with fantasy and dreams of tomorrow". Although there were early minor problems with the park, it was a success, and after a month's operation, Disneyland was receiving over 20,000 visitors a day; by the end of its first year, it attracted 3.6 million guests.

The money from ABC was contingent on Disney television programs. The studio had been involved in a successful television special on Christmas Day 1950 about the making of Alice in Wonderland. Roy believed the program added millions to the box office takings. In a March 1951 letter to shareholders, he wrote that "television can be a most powerful selling aid for us, as well as a source of revenue. It will probably be on this premise that we enter television when we do". In 1954, after the Disneyland funding had been agreed, ABC broadcast Walt Disney's Disneyland, an anthology consisting of animated cartoons, live-action features and other material from the studio's library. The show was successful in terms of ratings and profits, earning an audience share of over 50%. In April 1955, Newsweek called the series an "American institution". ABC was pleased with the ratings, leading to Disney's first daily television program, The Mickey Mouse Club, a variety show catering specifically to children. The program was accompanied by merchandising through various companies (Western Printing, for example, had been producing coloring books and comics for over 20 years, and produced several items connected to the show). One of the segments of Disneyland consisted of the five-part miniseries Davy Crockett which, according to Gabler,

"became an overnight sensation". The show's theme song, "The Ballad of Davy Crockett", became internationally popular, and ten million records were sold. As a result, Disney formed his own record production and distribution entity, Disneyland Records.

As well as the construction of Disneyland, Disney worked on other projects away from the studio. He was consultant to the 1959 American National Exhibition in Moscow; Disney Studios' contribution was America the Beautiful, a 19-minute film in the 360-degree Circarama theater that was one of the most popular attractions. The following year he acted as the chairman of the Pageantry Committee for the 1960 Winter Olympics in Squaw Valley, California, where he designed the opening, closing and medal ceremonies.

Despite the demands wrought by non-studio projects, Disney continued to work on film and television projects. In 1955, he was involved in "Man in Space", an episode of the Disneyland series, which was made in collaboration with NASA rocket designer Wernher von Braun. Disney also oversaw aspects of the full-length features Lady and the Tramp (the first animated film in CinemaScope) in 1955, Sleeping Beauty (the first animated film in Technirama 70 mm film) in 1959, One Hundred and One Dalmatians (the first animated feature film to use Xerox cels) in 1961, and The Sword in the Stone in 1963.

In 1964, Disney produced Mary Poppins, based on the book series by P. L. Travers; he had been trying to acquire the rights to the story since the 1940s. It became the most successful Disney film of the 1960s, although Travers disliked the film intensely and regretted having sold the rights. The same year he also became involved in plans to expand the California Institute of the Arts (colloquially called CalArts), and had an architect draw up blueprints for a new building.

Disney provided four exhibits for the 1964 New York World's Fair, for which he obtained funding from selected corporate sponsors. For PepsiCo, who planned a tribute to UNICEF, Disney developed It's a Small World, a boat ride with audio-animatronic dolls depicting children of the world; Great Moments with Mr. Lincoln contained an animatronic Abraham Lincoln giving excerpts from his speeches; Carousel of Progress promoted the importance of electricity; and Ford's Magic Skyway portrayed the progress of mankind. Elements of all four exhibits—principally concepts and technology—were re-installed in Disneyland, although It's a Small World is the ride that most closely resembles the original.

The Ford's Magic Skyway had been reworked into the peoplemover which took park guests for a trip around the tomorrowland section of Disneyland. The peoplemover was later transformed into Rocket Rods providing a faster and more trilling ride. Unfortunately the foundation of the peoplemover was not build for the forces delivered by the Rocket Rods, so after only two years of operation, the ride had to be closed permanently. Because the track of the Peoplemover goes around the entirety of tomorrowland and goes over most main walkways, to repair or dismantel the track, the tomorrowland section of the park has to be completly closed. Therefore the track still sits abandoned in the park till this day reminding fans of what ones was a fan favorite ride.

The other rides of the World's fair still operate to this day. The only change that has happend is that the Carousel of Progress has been moved to the Magic

Kingdom in Orlando, Florida.

During the early to mid-1960s, Disney developed plans for a ski resort in Mineral King, a glacial valley in California's Sierra Nevada. He hired experts such as the renowned Olympic ski coach and ski-area designer Willy Schaeffler. With income from Disneyland accounting for an increasing proportion of the studio's income, Disney continued to look for venues for other attractions. In late 1965, he announced plans to develop another theme park to be called "Disney World" (now Walt Disney World), a few miles southwest of Orlando, Florida. Disney World was to include the "Magic Kingdom"—a larger and more elaborate version of Disneyland—plus golf courses and resort hotels. The heart of Disney World was to be the "Experimental Prototype Community of Tomorrow" (EPCOT), which he described as:

> an experimental prototype community of tomorrow that will take its cue from the new ideas and new technologies that are now emerging from the creative centers of American industry. It will be a community of tomorrow that will never be completed, but will always be introducing and testing and demonstrating new materials and systems. And EPCOT will always be a showcase to the world for the ingenuity and imagination of American free enterprise.

During 1966, Disney cultivated businesses willing to sponsor EPCOT. He increased his involvement in the studio's films, and was heavily involved in the story development of The Jungle Book, the live-action musical feature The Happiest Millionaire (both 1967) and the animated short Winnie the Pooh and the Blustery Day (1968).

Illness, death and aftermath

Disney had been a heavy smoker since World War I. He did not use cigarettes with filters and had smoked a pipe as a young man. In early November 1966, he was diagnosed with lung cancer and was treated with cobalt therapy. On November 30, he felt unwell and was taken by ambulance from his home to St. Joseph Hospital where, on December 15, 1966 ten days after his 65th birthday, he died of circulatory collapse caused by the cancer. His remains were cremated two days later and his ashes interred at the Forest Lawn Memorial Park in Glendale, California.

The release of The Jungle Book and The Happiest Millionaire in 1967 raised the total number of feature films that Disney had been involved in to 81. When Winnie the Pooh and the Blustery Day was released in 1968, it earned Disney an Academy Award in the Short Subject (Cartoon) category, awarded posthumously. After Disney's death, his studios continued to produce live-action films prolifically but largely abandoned animation until the late 1980s, after which there was what The New York Times describes as the "Disney Renaissance" that began with The Little Mermaid (1989). Disney's companies continue to produce successful film, television and stage entertainment.

Disney's plans for the futuristic city of EPCOT did not come to fruition. After Disney's death, his brother Roy deferred his retirement to take full control of the Disney companies. He changed the focus of the project from a town to an attraction. At the inauguration in 1971, Roy dedicated Walt Disney World to his

brother. Walt Disney World expanded with the opening of Epcot Center in 1982; Walt Disney's vision of a functional city was replaced by a park more akin to a permanent world's fair. The park is split up into two parts: future showcase and world showcase. The future showcase part features rides focuses on future technology. The world showcase features pavilions sponsored by different countries around the world. All the pavilions are designed to resamble architecture famous to the specific country. The shops and restaurants in the pavilions sells products that are specific to the country. For example, the japan pavilion sells sushi and features a famous japanese wholesale store, the England pavilion sells famous english tea, etcetera. Disney employes people from the countries at the world showcase to work at the pavilion of there home country as part of the Disney College Program. The nice thing about this, is that if you go to, for example, the Germany pavilion, chances are that if you speak German to the employee, the employee can also respond in German.

Although Walts original ideas for EPCOT never came to fruition, a remnant of his plans can still be found inside the parks. When the Magic Kingdom was build, a copy of Disneylands tomorrowland was build and with it a copy of the Peoplemover, originally build for the New York World's Fair. When envisioning EPCOT, Walt build a detailed maquette of his ideas. This maquette has been preserved and a part of this can still be seen in one of the darkride sections of the Peoplemover in the Magic Kingdom.

In 2009, the Walt Disney Family Museum, designed by Disney's daughter Diane and her son Walter E. D. Miller, opened in the Presidio of San Francisco. Thousands of artifacts from Disney's life and career are on display, including numerous awards that he received. In 2014, the Disney theme parks around the world hosted approximately 134 million visitors.

Disney has been portrayed numerous times in fictional works. H. G. Wells references Disney in his 1938 novel The Holy Terror, in which World Dictator Rud fears that Donald Duck is meant to lampoon the dictator. Disney was portrayed by Len Cariou in the 1995 made-for-TV film A Dream Is a Wish Your Heart Makes: The Annette Funicello Story, and by Tom Hanks in the 2013 film Saving Mr. Banks. In 2001, the German author Peter Stephan Jungk published Der König von Amerika (trans: The King of America), a fictional work of Disney's later years that re-imagines him as a power-hungry racist. The composer Philip Glass later adapted the book into the opera The Perfect American (2013).

Additional information

Disneyland was partially Walt Disney's personal playground. Disney was a big fan of trains and he could often be found riding the train at the park, wearing a train-riders-cap and with a big smile on his head! This was mostly the reason Disneyland featured a train bringing guests around the park. This later became an iconic part of amusementparks around the world.

When Disneyland opened, the opening was far from perfect. The park quickly reached capacity which meant the entrance gates had to be closed. Many guests who did not manage to get into the park before capacity had been reached grabbed ladders and sneaked over the fences of the park. Some even went so far to rent there ladder to other people wanting to enter the parks. Because the

construction was rushed in the end, the tarmac was not fully dried yet. Because of this and because of the high heat at openingday, the tarmac started to melt, making peoples shoes stick to the road.

Many people were complaning about the rides in the park. The main complaint was that the main characters of the rides like snow white, peter pan and mr toad where no where to be seen in the rides. The rides where created with the idea that the rider is the main character, but people did not get this and complained about the absence of the characters. On top of that, the snow white ride was made scary, but unknowing parents did not expect this, bringing there small children expecting a nice light hearted ride, but getting out with terrified children.

From the beginning of Disneyland, it has been a "dry" park. No alcoholic beverages could be found in the park. This was because Walt did not want adults getting drunk and rowdy. To make sure he and other VIPS could still enjoy a drink, he created club 33. This is an exclusive club where only VIPS can come to eat an drink and this is the only part in Disneyland where alcohol is served.

Walt Disney used to have an apartement inside the park. The apartement can be found above the Firedepartement in Main Street USA with a window looking over the park. When Walt was at his apartement, a light in the window overlooking town squeare would be turned on to show that Walt was present in his apartement. After Walt passed away, the light has always been kept turned on as a memorial. The light now symoblizes Walt Disney's spirit and presence at Disneyland. The light is only turned off when his daughters visit out of respect for the family.

Disneyland Paris

Following the success of Disneyland in California, top to the plans to build a similar theme park in Europe emerged in 1966 with sites in Frankfurt, Paris, London or Milan under consideration. Under the leadership of E. Cardon Walker, Tokyo Disneyland opened in 1983 in Japan with instant success, forming a catalyst for international expansion. In late 1984 the heads of Disney's theme park division, Dick Nunis and Jim Cora, presented a list of approximately 1,200 possible European locations for the park. Britain, France, Italy and Spain were all considered. However, Britain and Italy were dropped from the list due to both lacking a suitable expanse of flat land. By March 1985, the number of possible locations for the park had been reduced to four; two in France and two in Spain. Both nations saw the potential economic advantages of a Disney theme park and offered competing financing deals to Disney.

Both Spanish sites were located near the Mediterranean and offered a subtropical climate similar to Disney's parks in California and Florida. Disney had asked each site to provide average temperatures for every month for the previous 40 years, which proved a complicated endeavour as none of the records were computerised and were registered on paper. The site in Pego, Alicante became the front-runner, but the location was controversial as it would have meant the destruction of Marjal de Pego-Oliva marshlands, a site of natural beauty and one of the last homes of the almost extinct Samaruc or Valencia Toothcarp, so there was some local outcry among environmentalists. Disney had also shown interest in a site near Toulon in southern France, not far from Marseille. The pleasing

landscape of that region, as well as its climate, made the location a top competitor for what would be called Euro Disneyland. However, shallow bedrock was encountered beneath the site, which would have rendered construction too difficult. Finally, a site in the rural town of Marne-la-Vallée was chosen because of its proximity to Paris and its central location in Western Europe. This location was estimated to be no more than a four-hour drive for 68 million people and no more than a two-hour flight for a further 300 million.

Michael Eisner, Disney's CEO at the time, signed the first letter of agreement with the French government for the 20-square-kilometre (4,940-acre) site on 18 December 1985, and the first financial contracts were drawn up during the following spring. The final contract was signed by the leaders of the Walt Disney Company and the French government and territorial collectivities on 24 March 1987. Construction began in August 1988, and in December 1990, an information centre named "Espace Euro Disney" was opened to show the public what was being constructed. Plans for a theme park next to Euro Disneyland based on the entertainment industry, Disney-MGM Studios Europe, quickly went into development, scheduled to open in 1996 with a construction budget of US$2.3 billion. The construction manager was Bovis.

In order to provide lodging to patrons, it was decided that 5,200 Disney-owned hotel rooms would be built within the complex. In March 1988, Disney and a council of architects (Frank Gehry, Michael Graves, Robert A.M. Stern, Stanley Tigerman, and Robert Venturi) decided on an exclusively American theme in which each hotel would depict a region of the United States. At the time of the opening in April 1992, seven hotels collectively housing 5,800 rooms had been built.

An entertainment, shopping, and dining complex based on Walt Disney World's Downtown Disney was designed by Frank Gehry.

With its towers of oxidised silver and bronze-coloured stainless steel under a canopy of lights, it opened as Festival Disney. For a projected daily attendance of 55,000, Euro Disney planned to serve an estimated 14,000 people per hour inside the Euro Disneyland park. In order to accomplish this, 29 restaurants were built inside the park (with a further 11 restaurants built at the Euro Disney resort hotels and five at Festival Disney). Menus and prices were varied with an American flavour predominant and Disney's precedent of not serving alcoholic beverages was continued in the park.

2,300 patio seats (30% of park seating) were installed to satisfy Europeans' expected preference of eating outdoors in good weather. In test kitchens at Walt Disney World, recipes were adapted for European tastes. Walter Meyer, executive chef for menu development at Euro Disney and executive chef of food projects development at Walt Disney World noted, "A few things we did need to change, but most of the time people kept telling us, 'Do your own thing. Do what's American'."

Unlike Disney's American theme parks, Euro Disney aimed for permanent employees (an estimated requirement of 12,000 for the theme park itself), as opposed to seasonal and temporary part-time employees. Casting centres were set up in Paris, London, and Amsterdam. However, it was understood by the French government and Disney that "a concentrated effort would be made to tap into the local French labour market". Disney sought workers with sufficient communication

skills, who spoke two European languages (French and one other), and were socially outgoing. Following precedent, Euro Disney set up its own Disney University to train workers. 24,000 people had applied by November 1991.

The prospect of a Disney park in France was a subject of debate and controversy. Critics, who included prominent French intellectuals, denounced what they considered to be the cultural imperialism of Euro Disney and felt it would encourage an unhealthy American type of consumerism in France. On 28 June 1992, a group of French farmers blockaded Euro Disney in protest of farm policies supported at the time by the United States.

A journalist at the centre-right French newspaper Le Figaro wrote, "I wish with all my heart that the rebels would set fire to Disneyland." Ariane Mnouchkine, a Parisian stage director, named the concept a "cultural Chernobyl", a phrase which would be echoed in the media during Euro Disney's initial years.

In response, French philosopher Michel Serres noted, "It is not America that is invading us. It is we who adore it, who adopt its fashions and above all, its words." Euro Disney S.C.A.'s then-chairman Robert Fitzpatrick responded, "We didn't come in and say O.K., we're going to put a beret and a baguette on Mickey Mouse. We are who we are."

Topics of controversy also included Disney's American managers requiring English to be spoken at all meetings and Disney's appearance code for members of staff, which listed regulations and limitations for the use of makeup, facial hair, tattoos, jewellery, and more.

French labour unions mounted protests against the appearance code, which they saw as "an attack on individual liberty". Others criticised Disney as being insensitive to French culture, individualism, and privacy, because restrictions on individual or collective liberties were illegal under French law, unless it could be demonstrated that the restrictions are requisite to the job and do not exceed what is necessary.

Disney countered by saying that a ruling that barred them from imposing such an employment standard could threaten the image and long-term success of the park. "For us, the appearance code has a great effect from a product identification standpoint," said Thor Degelmann, Euro Disney's personnel director. "Without it we couldn't be presenting the Disney product that people would be expecting."

Euro Disney opened for employee preview and testing in March 1992. During this time visitors were mostly park employees and their family members, who tested facilities and operations. The press was able to visit the day before the park's opening day on 12 April 1992.

On 12 April 1992, Euro Disney Resort and its theme park, Euro Disneyland, officially opened (on the same date that Mediaset's La Cinq TV channel closed permanently). Visitors were warned of chaos on the roads. A government survey indicated that half a million people carried by 90,000 cars might attempt to enter the complex. French radio warned traffic to avoid the area. By midday, the car park was approximately half full, suggesting an attendance level below 25,000. Explanations of the lower-than-expected turnout included speculation that people heeded the advice to stay away and that the one-day strike that cut the direct RER railway connection to Euro Disney from the centre of Paris made

the park inaccessible. Due to the European recession that August, the park faced financial difficulties as there were a lack of things to do and an overabundance of hotels, leading to underperformance.

Just like in the American parks, no alcohol was served in Disneyland Paris. The French people found this to be an attack on there culture since they were not able to drink wine at diner, something that is part of French culture. Another problem mistake the Americans made is the assumption that travel distances work the same as in America. Because of the size of the cities and the distance between cities, Americans are used to driving longer distances to get to a destination. They assumed this would also be the case in Europe, making people from all countries of Europe come to Disneyland. The problem is that Europeans are not used to this, so the majoraty of the guests came from France, rather then from every country.

A new Indiana Jones roller-coaster ride was opened at Euro Disney in 1993. A few weeks after the ride opened there were problems with the emergency brakes which resulted in guest injuries.

In 1994, the company was still having financial difficulties. There were rumours that Euro Disney was getting close to having to file for bankruptcy. The banks and the backers had meetings to work out some of the financial problems facing Euro Disney. In March 1994 Team Disney went into negotiations with the banks so that they could get some help for their debt. As a last resort, the Walt Disney Company threatened to close the Disneyland Paris park, leaving the banks with the land.

In May 1992, entertainment magazine The Hollywood Reporter reported that about 25% of Euro Disney's workforce – approximately 3,000 people – had resigned from their jobs because of unacceptable working conditions. It also reported that the park's attendance was far behind expectations. The disappointing attendance can be at least partly explained by the recession and increased unemployment, which was affecting France and most of the rest of the developed world at this time; when construction of the resort began, the economy was still on an upswing.

Euro Disney S.C.A. responded in an interview with The Wall Street Journal, in which Robert Fitzpatrick claimed only 1,000 people had left their jobs. In response to the financial situation, Fitzpatrick ordered that the Disney-MGM Studios Europe project would be put on halt until a further decision could be made. Prices at the hotels were reduced.

Despite these efforts in May 1992, park attendance was around 25,000 (some reports give a figure of 30,000) instead of the predicted 60,000. The Euro Disney Company stock price spiraled downwards and on 23 July 1992, Euro Disney announced an expected net loss in its first year of operation of approximately 300 million French francs. During Euro Disney's first winter, hotel occupancy was so low that it was decided to close the Newport Bay Club hotel during the season.

Initial hopes were that each visitor would spend around US$33 per day, but near the end of 1992, analysts found spending to be around 12% lower. Efforts to improve attendance included serving alcoholic beverages with meals inside the Euro Disneyland park, in response to a presumed European demand, which began 12 June 1993.

By the summer of 1994, Euro Disney was burdened with $3 billion worth of debt. Disney CFO Richard Nanula and Wall Street financier Steve Norris worked with Alwaleed's business advisor Mustafa Al Hejailan to rescue the overleveraged company. In that deal, the Walt Disney Corporation's 49 percent stake was reduced to 39 percent, the banks agreed to forego interest payments until 1997, Disney wrote off royalties and fees until 1999, and Alwaleed agreed to pay $345 million for a 24 percent stake in Euro Disney.

On October 1, 1994, Euro Disney changed its name to Disneyland Paris. On 31 May 1995, a new attraction opened at the theme park. Space Mountain: De la Terre à la Lune had been planned since the inception of Disneyland Paris under the name Discovery Mountain, but was reserved for a revival of public interest. With a redesign of the attraction (which had premiered as Space Mountain at the Walt Disney World Resort's Magic Kingdom in 1975) including a "cannon launch" system, inversions, and an on-ride soundtrack, the US$100 million attraction was dedicated in a ceremony attended by celebrities such as Elton John, Claudia Schiffer, and Buzz Aldrin. The ride was themed after the Jule Vergne story "to the moon and back". The idea behind this was to overcome the "tomorrowland issue". By giving the ride a steam-punk, alternate futuristic look, it would not become "old" after time. The problem with the tomorrowlands in America is that it tries to showcase a realistic future, but after 10 years or so, this future becomes reality making everything look old and outdated. Space Mountain was designed by the now legendary Disney Imagineer Tony Baxter, who was responsible for the design of Disneyland Paris. Space Mountain saved Disneyland Paris from going under.

On 25 July 1995, Disneyland Paris reported its first quarterly profit of US$35.3 million. On 15 November 1995, the results for the fiscal year ending 30 September 1995, were released; in one year the theme park's attendance had climbed from 8.8 million to 10.7 million – an increase of 21%. Hotel occupancy had also climbed from 60 to 68.5%. After debt payments, Disneyland Paris ended the year with a net profit of US$22.8 million.

In march of 2002, the second gate "Walt Disney Studios Park" opened at Disneyland Resort Paris (further called WDSP). Because of the agreement Disney had with the French governement, they where obligated to build a second gate before a certain amount of years of opening. The problem Disney faced was that Disneyland did not make a huge provid and because of this did not have a hugh budget to create the second gate. The result: WDSP, a park with too few rides, made as cheap as possible!

As of March 2002, Disneyland Paris underwent a second name change to Disneyland Resort Paris. In 2002, Euro Disney S.C.A. and the Walt Disney Company announced another annual profit for Disneyland Paris. However, it then incurred a net loss in the three years following. By March 2004, the Walt Disney Company had agreed to write off all debt that Euro Disney S.C.A. owed to the Walt Disney Company. On 1 December 2003, Euro Disney S.C.A launched the 'Need Magic' campaign, which lasted until March 2006 to bring new, first-time European visitors to the resort. And by 2005, having been open fewer than fifteen years, Disneyland Paris had become the number one tourist destination for Europe, outselling the Louvre and the Eiffel Tower.

In March 2006, Disneyland Resort Paris launched the advertising campaign,

"believe in your dreams" and paired with the TGV East European Line to encourage European family attendance to the resort. Shortly after announcing a 12% increase in revenues for the fiscal year of 2007, Euro Disney S.C.A. implemented a "reverse split" consolidation of shares of 100 to 1. August 2008 brought the resort's 200 millionth visitor, and made for the third consecutive year of growth in revenues for the resort as well as record a record of 15.3 million visitors in attendance.

In 2009, the resort demonstrated dedication to the recruitment of new employment positions, especially for the Christmas and summer seasons, which continued in 2010 and 2011 when 2,000 and 3,000 employment contracts being offered, respectively. The 2009 fiscal year saw a decrease in revenues by 7% and a net loss of 63 million followed by stable revenues at 1.2 billion in fiscal 2010. Euro Disney S.C.A. refinanced their debt to Walt Disney Company again for 1.3 billion euros in September 2012.

A study done by the Inter-ministerial Delegation reviewing Disneyland Paris' contribution to the French economy was released in time for the Resort's 20th anniversary in March 2012. It found that despite the resort's financial hardships, it has generated "37 billion euros in tourism-related revenues over twenty years", supports on average 55,000 jobs in France annually, and that one job at Disneyland Paris generates nearly three jobs elsewhere in France.

For the first time in the resort's history, both the Disneyland Park and Walt Disney Studios Park closed from 14 to 17 November 2015, as part of France's national days of mourning following the November 2015 Paris attacks.

On 19 June 2017, the resort's operating company, Euro Disney S.C.A, was acquired by The Walt Disney Company, in the process, giving them full control of the resort. In December 2018, Natacha Rafalski took over as CEO. On 1 September 2017 the resort's second nature resort opened as Les Villages Nature Paris.

On 27 February 2018, Walt Disney Company CEO Bob Iger announced that company would invest €2 billion into the Disneyland Paris resort. The Walt Disney Studios Park will be expanded with three new areas based upon Marvel, Frozen and Star Wars. In addition to the three new areas, the expansion includes a new lake, which will be the focal point for entertainment experiences and will also connect each of the new park areas. The first phase of the expansion will be completed in 2021. Part of this expansion also include a retheme of the Studio Tramtour into a Cars ride. Because the tramtour was located in the center of the park, it had to go to acommodate the new expansions. The problem is that the studios park already suffers from a lack of capacity, completely removing a ride would not be possible. Therefore the ride is rethemed and the station is relocated. Only the right half of the track will remain and only one scene of the ride (catastrophy canyon) still remains. This scene is rethemed to the Cars IP. The ride is set to reopen this year. (Personal note from Jeffrey to make this text a little bit longer because I already had to put together two hugh wikipedia pages and it is still not enough :-) : The retheme seems to be really cheaply done. I expect that this retheme is only done because it would really hurt the capacity of the park if this ride would be removed, especially if you consider that this ride has a scarily large capacity. Something had to happen because the road that leads to the new lake would have to go straight through the old tram tour station. Therefore they opted to remove the left part of the track, creating more place for the new/rethemed Marvel section, and kept the

unused part on the ride to keep the tram tours capacity. I think that when the expansion of the park with the three new lands is done, the tram tour will be next on the list to be removed. This will created a nice plot of land to create a new ride, maybe with an expansion of the Toy Story or France land. But sorry for the interruption, I will not keep you waiting any longer and let you continue with the nice story you have been reading which should not take too long to complete from here on. And yes, I am still trying to expand the amount on non-sense in this section to make the text longer. I am going to continue making the questionnaire now! BYEEEEEEE) In April 2019, the location hosted a Dota 2 esports tournament.

In March 2018, a Disney Parks West regional division was formed with Disneyland Resort in California, Walt Disney World in Florida, and Disneyland Paris under Catherine Powell, outgoing Disneyland Paris president. This mirrors the Disney Parks East regional division consisting of Shanghai Disney Resort, Hong Kong Disneyland and Walt Disney Attractions Japan and headed by Michael Colglazier. Natacha Rafalski was promoted from chief financial officer to president for Disneyland Paris in December 2018. In September 2019, Powell exited her post as president of the park west division with division dissolving and Disneyland Paris transferred to Disney Parks International, East region reverting to its prior name.

On 1 June 2019, Disneyland Paris sponsored the Magical Pride Party, an LGBTQ celebration. Previous similar events have taken place at the park since 2014, but were not officially sponsored by Disney.

On 15 March 2020, in line with other Disney parks and resorts, Disneyland Paris was shut down due to the worldwide COVID-19 pandemic. Disneyland Park and Walt Disney Studios Park reopened to the public on 15 July with the rest of the resort. On 29 October 2020, the resort closed again due a second nationwide lockdown. In May 2021, Disneyland Paris announced that it will re-open on June 17. The park is currently not opened.

Estimated time: 36 minutes
Sources: https://nl.wikipedia.org/wiki/Walt_Disney and https://en.wikipedia.org/wiki/Disneyland_Paris

C.3.2 ISS

Introduction

The International Space Station (ISS) is a modular space station (habitable artificial satellite) in low Earth orbit. It is a multinational collaborative project involving five participating space agencies: NASA (United States), Roscosmos (Russia), JAXA (Japan), ESA (Europe), and CSA (Canada). The ownership and use of the space station is established by intergovernmental treaties and agreements. The station serves as a microgravity and space environment research laboratory in which scientific research is conducted in astrobiology, astronomy, meteorology, physics, and other fields. The ISS is suited for testing the spacecraft systems and equipment required for possible future long-duration missions to the Moon and Mars.

The ISS programme evolved from the Space Station Freedom, an American proposal which was conceived in 1984 to construct a permanently manned Earth-orbiting station, and the contemporaneous Soviet/Russian Mir-2 proposal with similar aims. The ISS is the ninth space station to be inhabited by crews, following the Soviet and later Russian Salyut, Almaz, and Mir stations and the U.S. Skylab. It is the largest artificial object in space and the largest satellite in low Earth orbit, regularly visible to the naked eye from Earth's surface. It maintains an orbit with an average altitude of 400 kilometres (250 mi) by means of reboost manoeuvres using the engines of the Zvezda Service Module or visiting spacecraft. The ISS circles the Earth in roughly 93 minutes, completing 15.5 orbits per day.

The station is divided into two sections: the Russian Orbital Segment (ROS) is operated by Russia, while the United States Orbital Segment (USOS) is run by the United States as well as many other nations. Roscosmos has endorsed the continued operation of ROS through 2024, having previously proposed using elements of the segment to construct a new Russian space station called OPSEK. The first ISS component was launched in 1998, and the first long-term residents arrived on 2 November 2000 after being launched from the Baikonur Cosmodrome on 31 October 2000. The station has since been continuously occupied for 20 years and 203 days, the longest continuous human presence in low Earth orbit, having surpassed the previous record of 9 years and 357 days held by the Mir space station. The latest major pressurised module, Leonardo, was fitted in 2011 and an experimental inflatable space habitat was added in 2016. Development and assembly of the station continues, with several major new Russian elements scheduled for launch starting in 2021. As of December 2018, the station's operation authorization was extended to 2030, with funding secured until 2025. There have been calls to privatize ISS operations after that point to pursue future Moon and Mars missions, with former NASA Administrator Jim Bridenstein saying "given our current budget constraints, if we want to go to the moon and we want to go to Mars, we need to commercialize low Earth orbit and go on to the next step."

The ISS consists of pressurised habitation modules, structural trusses, photovoltaic solar arrays, thermal radiators, docking ports, experiment bays and robotic arms. Major ISS modules have been launched by Russian Proton and Soyuz rockets and US Space Shuttles. The station is serviced by a variety of visiting spacecraft: the Russian Soyuz and Progress, the SpaceX Dragon 2, the Northrop Grumman Innovation Systems Cygnus, the Japanese H-II Transfer Vehicle, and,

formerly, the European Automated Transfer Vehicle (ATV) and SpaceX Dragon 1. The Dragon spacecraft allows the return of pressurised cargo to Earth, which is used, for example, to repatriate scientific experiments for further analysis. As of November 2020, 242 astronauts, cosmonauts, and space tourists from 19 different nations have visited the space station, many of them multiple times; this includes 152 Americans, 49 Russians, 9 Japanese, 8 Canadians, and 5 Italians.

Purpose

The ISS was originally intended to be a laboratory, observatory, and factory while providing transportation, maintenance, and a low Earth orbit staging base for possible future missions to the Moon, Mars, and asteroids. However, not all of the uses envisioned in the initial memorandum of understanding between NASA and Roscosmos have been realised. In the 2010 United States National Space Policy, the ISS was given additional roles of serving commercial, diplomatic, and educational purposes.

Scientific research

The ISS provides a platform to conduct scientific research, with power, data, cooling, and crew available to support experiments. Small uncrewed spacecraft can also provide platforms for experiments, especially those involving zero gravity and exposure to space, but space stations offer a long-term environment where studies can be performed potentially for decades, combined with ready access by human researchers.

The ISS simplifies individual experiments by allowing groups of experiments to share the same launches and crew time. Research is conducted in a wide variety of fields, including astrobiology, astronomy, physical sciences, materials science, space weather, meteorology, and human research including space medicine and the life sciences. Scientists on Earth have timely access to the data and can suggest experimental modifications to the crew. If follow-on experiments are necessary, the routinely scheduled launches of resupply craft allows new hardware to be launched with relative ease. Crews fly expeditions of several months' duration, providing approximately 160 person-hours per week of labour with a crew of six. However, a considerable amount of crew time is taken up by station maintenance.

Perhaps the most notable ISS experiment is the Alpha Magnetic Spectrometer (AMS), which is intended to detect dark matter and answer other fundamental questions about our universe and is as important as the Hubble Space Telescope according to NASA. Currently docked on station, it could not have been easily accommodated on a free flying satellite platform because of its power and bandwidth needs. On 3 April 2013, scientists reported that hints of dark matter may have been detected by the AMS. According to the scientists, "The first results from the space-borne Alpha Magnetic Spectrometer confirm an unexplained excess of high-energy positrons in Earth-bound cosmic rays".

The space environment is hostile to life. Unprotected presence in space is characterised by an intense radiation field (consisting primarily of protons and other subatomic charged particles from the solar wind, in addition to cosmic

rays), high vacuum, extreme temperatures, and microgravity. Some simple forms of life called extremophiles, as well as small invertebrates called tardigrades can survive in this environment in an extremely dry state through desiccation.

Medical research improves knowledge about the effects of long-term space exposure on the human body, including muscle atrophy, bone loss, and fluid shift. This data will be used to determine whether high duration human spaceflight and space colonisation are feasible. As of 2006, data on bone loss and muscular atrophy suggest that there would be a significant risk of fractures and movement problems if astronauts landed on a planet after a lengthy interplanetary cruise, such as the six-month interval required to travel to Mars.

Medical studies are conducted aboard the ISS on behalf of the National Space Biomedical Research Institute (NSBRI). Prominent among these is the Advanced Diagnostic Ultrasound in Microgravity study in which astronauts perform ultrasound scans under the guidance of remote experts. The study considers the diagnosis and treatment of medical conditions in space. Usually, there is no physician on board the ISS and diagnosis of medical conditions is a challenge. It is anticipated that remotely guided ultrasound scans will have application on Earth in emergency and rural care situations where access to a trained physician is difficult.

In August 2020, scientists reported that bacteria from Earth, particularly Deinococcus radiodurans bacteria, which is highly resistant to environmental hazards, were found to survive for three years in outer space, based on studies conducted on the International Space Station. These findings supported the notion of panspermia, the hypothesis that life exists throughout the Universe, distributed in various ways, including space dust, meteoroids, asteroids, comets, planetoids or contaminated spacecraft.

Remote sensing of the Earth, astronomy, and deep space research on the ISS have dramatically increased during the 2010s after the completion of the US Orbital Segment in 2011. Throughout the more than 20 years of the ISS program researchers aboard the ISS and on the ground have examined aerosols, ozone, lightning, and oxides in Earth's atmosphere, as well as the Sun, cosmic rays, cosmic dust, antimatter, and dark matter in the universe. Examples of Earth-viewing remote sensing experiments that have flown on the ISS are the Orbiting Carbon Observatory 3, ISS-RapidScat, ECOSTRESS, the Global Ecosystem Dynamics Investigation, and the Cloud Aerosol Transport System. ISS-based astronomy telescopes and experiments include SOLAR, the Neutron Star Interior Composition Explorer, the Calorimetric Electron Telescope, the Monitor of All-sky X-ray Image (MAXI), and the Alpha Magnetic Spectrometer.

Freefall

Gravity at the altitude of the ISS is approximately 90% as strong as at Earth's surface, but objects in orbit are in a continuous state of freefall, resulting in an apparent state of weightlessness. This perceived weightlessness is disturbed by five separate effects:

- Drag from the residual atmosphere.
- Vibration from the movements of mechanical systems and the crew.
- Actuation of the on-board attitude control moment gyroscopes.

Thruster firings for attitude or orbital changes.

Gravity-gradient effects, also known as tidal effects. Items at different locations within the ISS would, if not attached to the station, follow slightly different orbits. Being mechanically interconnected these items experience small forces that keep the station moving as a rigid body.

Researchers are investigating the effect of the station's near-weightless environment on the evolution, development, growth and internal processes of plants and animals. In response to some of this data, NASA wants to investigate microgravity's effects on the growth of three-dimensional, human-like tissues, and the unusual protein crystals that can be formed in space.

Exploration

The ISS provides a location in the relative safety of low Earth orbit to test spacecraft systems that will be required for long-duration missions to the Moon and Mars. This provides experience in operations, maintenance as well as repair and replacement activities on-orbit, which will be essential skills in operating spacecraft farther from Earth, mission risks can be reduced and the capabilities of interplanetary spacecraft advanced. Referring to the MARS-500 experiment, ESA states that "Whereas the ISS is essential for answering questions concerning the possible impact of weightlessness, radiation and other space-specific factors, aspects such as the effect of long-term isolation and confinement can be more appropriately addressed via ground-based simulations". Sergey Krasnov, the head of human space flight programmes for Russia's space agency, Roscosmos, in 2011 suggested a "shorter version" of MARS-500 may be carried out on the ISS.

In 2009, noting the value of the partnership framework itself, Sergey Krasnov wrote, "When compared with partners acting separately, partners developing complementary abilities and resources could give us much more assurance of the success and safety of space exploration. The ISS is helping further advance near-Earth space exploration and realisation of prospective programmes of research and exploration of the Solar system, including the Moon and Mars." A crewed mission to Mars may be a multinational effort involving space agencies and countries outside the current ISS partnership. In 2010, ESA Director-General Jean-Jacques Dordain stated his agency was ready to propose to the other four partners that China, India and South Korea be invited to join the ISS partnership. NASA chief Charles Bolden stated in February 2011, "Any mission to Mars is likely to be a global effort". Currently, US federal legislation prevents NASA co-operation with China on space projects.

Investigating the physics of fluids in microgravity will provide better models of the behaviour of fluids. Because fluids can be almost completely combined in microgravity, physicists investigate fluids that do not mix well on Earth. In addition, examining reactions that are slowed by low gravity and low temperatures will improve our understanding of superconductivity.

The study of materials science is an important ISS research activity, with the objective of reaping economic benefits through the improvement of techniques used on the ground. Other areas of interest include the effect of the low gravity environment on combustion, through the study of the efficiency of burning and control of emissions and pollutants. These findings may improve current knowledge about energy production, and lead to economic and environmental benefits.

Education and cultural outreach

The ISS crew provides opportunities for students on Earth by running student-developed experiments, making educational demonstrations, allowing for student participation in classroom versions of ISS experiments, and directly engaging students using radio, videolink, and email. ESA offers a wide range of free teaching materials that can be downloaded for use in classrooms. In one lesson, students can navigate a 3D model of the interior and exterior of the ISS, and face spontaneous challenges to solve in real time.

JAXA aims to inspire children to "pursue craftsmanship" and to heighten their "awareness of the importance of life and their responsibilities in society". Through a series of education guides, students develop a deeper understanding of the past and near-term future of crewed space flight, as well as that of Earth and life. In the JAXA "Seeds in Space" experiments, the mutation effects of spaceflight on plant seeds aboard the ISS are explored by growing sunflower seeds that have flown on the ISS for about nine months. In the first phase of Kibō utilisation from 2008 to mid-2010, researchers from more than a dozen Japanese universities conducted experiments in diverse fields.

Cultural activities are another major objective of the ISS programme. Tetsuo Tanaka, the director of JAXA's Space Environment and Utilization Center, has said: "There is something about space that touches even people who are not interested in science."

Amateur Radio on the ISS (ARISS) is a volunteer programme that encourages students worldwide to pursue careers in science, technology, engineering, and mathematics, through amateur radio communications opportunities with the ISS crew. ARISS is an international working group, consisting of delegations from nine countries including several in Europe, as well as Japan, Russia, Canada, and the United States. In areas where radio equipment cannot be used, speakerphones connect students to ground stations which then connect the calls to the space station.

First Orbit is a 2011 feature-length documentary film about Vostok 1, the first crewed space flight around the Earth. By matching the orbit of the ISS to that of Vostok 1 as closely as possible, in terms of ground path and time of day, documentary filmmaker Christopher Riley and ESA astronaut Paolo Nespoli were able to film the view that Yuri Gagarin saw on his pioneering orbital space flight. This new footage was cut together with the original Vostok 1 mission audio recordings sourced from the Russian State Archive. Nespoli is credited as the director of photography for this documentary film, as he recorded the majority of the footage himself during Expedition 26/27. The film was streamed in a global YouTube premiere in 2011 under a free licence through the website firstorbit.org.

In May 2013, commander Chris Hadfield shot a music video of David Bowie's "Space Oddity" on board the station, which was released on YouTube. It was the first music video ever to be filmed in space.

In November 2017, while participating in Expedition 52/53 on the ISS, Paolo Nespoli made two recordings of his spoken voice (one in English and the other in his native Italian), for use on Wikipedia articles. These were the first content

made in space specifically for Wikipedia.

Construction

Manufacturing

Since the International Space Station is a multi-national collaborative project, the components for in-orbit assembly were manufactured in various countries around the world. Beginning in the mid 1990s, the U.S. components Destiny, Unity, the Integrated Truss Structure, and the solar arrays were fabricated at the Marshall Space Flight Center and the Michoud Assembly Facility. These modules were delivered to the Operations and Checkout Building and the Space Station Processing Facility (SSPF) for final assembly and processing for launch.

The Russian modules, including Zarya and Zvezda, were manufactured at the Khrunichev State Research and Production Space Center in Moscow. Zvezda was initially manufactured in 1985 as a component for Mir-2, but was never launched and instead became the ISS Service Module.

The European Space Agency (ESA) Columbus module was manufactured at the EADS Astrium Space Transportation facilities in Bremen, Germany, along with many other contractors throughout Europe. The other ESA-built modules—Harmony, Tranquility, the Leonardo MPLM, and the Cupola—were initially manufactured at the Thales Alenia Space factory in Turin, Italy. The structural steel hulls of the modules were transported by aircraft to the Kennedy Space Center SSPF for launch processing.[citation needed]

The Japanese Experiment Module Kibō, was fabricated in various technology manufacturing facilities in Japan, at the NASDA (now JAXA) Tsukuba Space Center, and the Institute of Space and Astronautical Science. The Kibo module was transported by ship and flown by aircraft to the SSPF.

The Mobile Servicing System, consisting of the Canadarm2 and the Dextre grapple fixture, was manufactured at various factories in Canada (such as the David Florida Laboratory) and the United States, under contract by the Canadian Space Agency. The mobile base system, a connecting framework for Canadarm2 mounted on rails, was built by Northrop Grumman. (Sidenote: the Canadarm2 is the big arm on top of the ISS used to, for example, dock spacecrafts and move modules during installation)

Assembly

The assembly of the International Space Station, a major endeavour in space architecture, began in November 1998. Russian modules launched and docked robotically, with the exception of Rassvet. All other modules were delivered by the Space Shuttle, which required installation by ISS and Shuttle crewmembers using the Canadarm2 (SSRMS) and extra-vehicular activities (EVAs); as of 5 June 2011, they had added 159 components during more than 1,000 hours of EVA. 127 of these spacewalks originated from the station, and the remaining 32 were launched from the airlocks of docked Space Shuttles. The beta angle of the station had to be considered at all times during construction.

The first module of the ISS, Zarya, was launched on 20 November 1998 on an autonomous Russian Proton rocket. It provided propulsion, attitude control, communications, electrical power, but lacked long-term life support functions. Two weeks later, a passive NASA module Unity was launched aboard Space Shuttle flight STS-88 and attached to Zarya by astronauts during EVAs. This module has two Pressurised Mating Adapters (PMAs), one connects permanently to Zarya, the other allowed the Space Shuttle to dock to the space station. At that time, the Russian station Mir was still inhabited, and the ISS remained uncrewed for two years. On 12 July 2000, Zvezda was launched into orbit. Preprogrammed commands on board deployed its solar arrays and communications antenna. It then became the passive target for a rendezvous with Zarya and Unity: it maintained a station-keeping orbit while the Zarya-Unity vehicle performed the rendezvous and docking via ground control and the Russian automated rendezvous and docking system. Zarya's computer transferred control of the station to Zvezda's computer soon after docking. Zvezda added sleeping quarters, a toilet, kitchen, CO2 scrubbers, dehumidifier, oxygen generators, exercise equipment, plus data, voice and television communications with mission control. This enabled permanent habitation of the station.

The first resident crew, Expedition 1, arrived in November 2000 on Soyuz TM-31 (Rusian rocket). At the end of the first day on the station, astronaut Bill Shepherd requested the use of the radio call sign "Alpha", which he and cosmonaut Krikalev preferred to the more cumbersome "International Space Station". The name "Alpha" had previously been used for the station in the early 1990s, and its use was authorised for the whole of Expedition 1. Shepherd had been advocating the use of a new name to project managers for some time. Referencing a naval tradition in a pre-launch news conference he had said: "For thousands of years, humans have been going to sea in ships. People have designed and built these vessels, launched them with a good feeling that a name will bring good fortune to the crew and success to their voyage." Yuri Semenov, the President of Russian Space Corporation Energia at the time, disapproved of the name "Alpha" as he felt that Mir was the first modular space station, so the names "Beta" or "Mir 2" for the ISS would have been more fitting.

Expedition 1 arrived midway between the flights of STS-92 and STS-97. These two Space Shuttle flights each added segments of the station's Integrated Truss Structure, which provided the station with Ku-band communication for US television, additional attitude support needed for the additional mass of the USOS, and substantial solar arrays supplementing the station's four existing solar arrays.

Over the next two years, the station continued to expand. A Soyuz-U rocket delivered the Pirs docking compartment. The Space Shuttles Discovery, Atlantis, and Endeavour delivered the Destiny laboratory and Quest airlock, in addition to the station's main robot arm, the Canadarm2, and several more segments of the Integrated Truss Structure.

The expansion schedule was interrupted by the Space Shuttle Columbia disaster in 2003 and a resulting hiatus in flights. The Space Shuttle was grounded until 2005 with STS-114 flown by Discovery.

Assembly resumed in 2006 with the arrival of STS-115 with Atlantis, which delivered the station's second set of solar arrays. Several more truss segments and a third set of arrays were delivered on STS-116, STS-117, and STS-118. As a

result of the major expansion of the station's power-generating capabilities, more pressurised modules could be accommodated, and the Harmony node and Columbus European laboratory were added. These were soon followed by the first two components of Kibō. In March 2009, STS-119 completed the Integrated Truss Structure with the installation of the fourth and final set of solar arrays. The final section of Kibō was delivered in July 2009 on STS-127, followed by the Russian Poisk module. The third node, Tranquility, was delivered in February 2010 during STS-130 by the Space Shuttle Endeavour, alongside the Cupola, followed in May 2010 by the penultimate Russian module, Rassvet. Rassvet was delivered by Space Shuttle Atlantis on STS-132 in exchange for the Russian Proton delivery of the US-funded Zarya module in 1998. The last pressurised module of the USOS, Leonardo, was brought to the station in February 2011 on the final flight of Discovery, STS-133. The Alpha Magnetic Spectrometer was delivered by Endeavour on STS-134 the same year.

As of June 2011, the station consisted of 15 pressurised modules and the Integrated Truss Structure. Five modules are still to be launched, including the Nauka with the European Robotic Arm, the Prichal module, and two power modules called NEM-1 and NEM-2. As of May 2020, Russia's future primary research module Nauka is set to launch in the spring of 2021, along with the European Robotic Arm which will be able to relocate itself to different parts of the Russian modules of the station.

The gross mass of the station changes over time. The total launch mass of the modules on orbit is about 417,289 kg (919,965 lb) (as of 3 September 2011). The mass of experiments, spare parts, personal effects, crew, foodstuff, clothing, propellants, water supplies, gas supplies, docked spacecraft, and other items add to the total mass of the station. Hydrogen gas is constantly vented overboard by the oxygen generators.

Onboard systems

Life support

The critical systems are the atmosphere control system, the water supply system, the food supply facilities, the sanitation and hygiene equipment, and fire detection and suppression equipment. The Russian Orbital Segment's life support systems are contained in the Zvezda service module. Some of these systems are supplemented by equipment in the USOS. The Nauka laboratory has a complete set of life support systems.

Atmospheric control system

The atmosphere on board the ISS is similar to that of Earth. Normal air pressure on the ISS is 101.3 kPa (14.69 psi); the same as at sea level on Earth. An Earth-like atmosphere offers benefits for crew comfort, and is much safer than a pure oxygen atmosphere, because of the increased risk of a fire such as that responsible for the deaths of the Apollo 1 crew. Earth-like atmospheric conditions have been maintained on all Russian and Soviet spacecraft.

The Elektron system aboard Zvezda and a similar system in Destiny generate oxygen aboard the station. The crew has a backup option in the form of bottled

oxygen and Solid Fuel Oxygen Generation (SFOG) canisters, a chemical oxygen generator system. Carbon dioxide is removed from the air by the Vozdukh system in Zvezda. Other by-products of human metabolism, such as methane from the intestines and ammonia from sweat, are removed by activated charcoal filters.

Part of the ROS atmosphere control system is the oxygen supply. Triple-redundancy is provided by the Elektron unit, solid fuel generators, and stored oxygen. The primary supply of oxygen is the Elektron unit which produces O2 and H2 by electrolysis of water and vents H2 overboard. The 1 kW (1.3 hp) system uses approximately one litre of water per crew member per day. This water is either brought from Earth or recycled from other systems. Mir was the first spacecraft to use recycled water for oxygen production. The secondary oxygen supply is provided by burning O2-producing Vika cartridges (see also ISS ECLSS). Each 'candle' takes 5–20 minutes to decompose at 450–500 °C (842–932 °F), producing 600 litres (130 imp gal; 160 US gal) of O2. This unit is manually operated.

The US Orbital Segment has redundant supplies of oxygen, from a pressurised storage tank on the Quest airlock module delivered in 2001, supplemented ten years later by ESA-built Advanced Closed-Loop System (ACLS) in the Tranquility module (Node 3), which produces O2 by electrolysis. Hydrogen produced is combined with carbon dioxide from the cabin atmosphere and converted to water and methane.

Power and thermal control

Double-sided solar arrays provide electrical power to the ISS. These bifacial cells collect direct sunlight on one side and light reflected off from the Earth on the other, and are more efficient and operate at a lower temperature than single-sided cells commonly used on Earth.

The Russian segment of the station, like most spacecraft, uses 28 V low voltage DC from two rotating solar arrays mounted on Zvezda. The USOS uses 130–180 V DC from the USOS PV array, power is stabilised and distributed at 160 V DC and converted to the user-required 124 V DC. The higher distribution voltage allows smaller, lighter conductors, at the expense of crew safety. The two station segments share power with converters.

The USOS solar arrays are arranged as four wing pairs, for a total production of 75 to 90 kilowatts. These arrays normally track the Sun to maximise power generation. Each array is about 375 m2 (4,036 sq ft) in area and 58 m (190 ft) long. In the complete configuration, the solar arrays track the Sun by rotating the alpha gimbal once per orbit; the beta gimbal follows slower changes in the angle of the Sun to the orbital plane. The Night Glider mode aligns the solar arrays parallel to the ground at night to reduce the significant aerodynamic drag at the station's relatively low orbital altitude.

The station originally used rechargeable nickel–hydrogen batteries (NiH2) for continuous power during the 45 minutes of every 90-minute orbit that it is eclipsed by the Earth. The batteries are recharged on the day side of the orbit. They had a 6.5-year lifetime (over 37,000 charge/discharge cycles) and were regularly replaced over the anticipated 20-year life of the station. Starting in 2016, the nickel–hydrogen batteries were replaced by lithium-ion batteries, which are expected to last until the end of the ISS program.

The station's large solar panels generate a high potential voltage difference between the station and the ionosphere. This could cause arcing through insulating surfaces and sputtering of conductive surfaces as ions are accelerated by the spacecraft plasma sheath. To mitigate this, plasma contactor units (PCU)s create current paths between the station and the ambient plasma field.
ISS External Active Thermal Control System (EATCS) diagram

The station's systems and experiments consume a large amount of electrical power, almost all of which is converted to heat. To keep the internal temperature within workable limits, a passive thermal control system (PTCS) is made of external surface materials, insulation such as MLI, and heat pipes. If the PTCS cannot keep up with the heat load, an External Active Thermal Control System (EATCS) maintains the temperature. The EATCS consists of an internal, non-toxic, water coolant loop used to cool and dehumidify the atmosphere, which transfers collected heat into an external liquid ammonia loop. From the heat exchangers, ammonia is pumped into external radiators that emit heat as infrared radiation, then back to the station. The EATCS provides cooling for all the US pressurised modules, including Kibō and Columbus, as well as the main power distribution electronics of the S0, S1 and P1 trusses. It can reject up to 70 kW. This is much more than the 14 kW of the Early External Active Thermal Control System (EEATCS) via the Early Ammonia Servicer (EAS), which was launched on STS-105 and installed onto the P6 Truss.

Communications and computers

Radio communications provide telemetry and scientific data links between the station and mission control centres. Radio links are also used during rendezvous and docking procedures and for audio and video communication between crew members, flight controllers and family members. As a result, the ISS is equipped with internal and external communication systems used for different purposes.

The Russian Orbital Segment communicates directly with the ground via the Lira antenna mounted to Zvezda. The Lira antenna also has the capability to use the Luch data relay satellite system. This system fell into disrepair during the 1990s, and so was not used during the early years of the ISS, although two new Luch satellites—Luch-5A and Luch-5B—were launched in 2011 and 2012 respectively to restore the operational capability of the system. Another Russian communications system is the Voskhod-M, which enables internal telephone communications between Zvezda, Zarya, Pirs, Poisk, and the USOS and provides a VHF radio link to ground control centres via antennas on Zvezda's exterior.

The US Orbital Segment (USOS) makes use of two separate radio links mounted in the Z1 truss structure: the S band (audio) and Ku band (audio, video and data) systems. These transmissions are routed via the United States Tracking and Data Relay Satellite System (TDRSS) in geostationary orbit, allowing for almost continuous real-time communications with Christopher C. Kraft Jr. Mission Control Center (MCC-H) in Houston. Data channels for the Canadarm2, European Columbus laboratory and Japanese Kibō modules were originally also routed via the S band and Ku band systems, with the European Data Relay System and a similar Japanese system intended to eventually complement the TDRSS in this role. Communications between modules are carried on an internal wireless network.

UHF radio is used by astronauts and cosmonauts conducting EVAs and other spacecraft that dock to or undock from the station. Automated spacecraft are fitted with their own communications equipment; the ATV uses a laser attached to the spacecraft and the Proximity Communications Equipment attached to Zvezda to accurately dock with the station.

The ISS is equipped with about 100 IBM/Lenovo ThinkPad and HP ZBook 15 laptop computers. The laptops have run Windows 95, Windows 2000, Windows XP, Windows 7, Windows 10 and Linux operating systems. Each computer is a commercial off-the-shelf purchase which is then modified for safety and operation including updates to connectors, cooling and power to accommodate the station's 28V DC power system and weightless environment. Heat generated by the laptops does not rise but stagnates around the laptop, so additional forced ventilation is required. Laptops aboard the ISS are connected to the station's wireless LAN via Wi-Fi and ethernet, which connects to the ground via Ku band. While originally this provided speeds of 10 Mbit/s download and 3 Mbit/s upload from the station, NASA upgraded the system in late August 2019 and increased the speeds to 600 Mbit/s. Laptop hard drives occasionally fail and must be replaced. Other computer hardware failures include instances in 2001, 2007 and 2017; some of these failures have required EVAs to replace computer modules in externally mounted devices.

The operating system used for key station functions is the Debian Linux distribution. The migration from Microsoft Windows to Linux was made in May 2013 for reasons of reliability, stability and flexibility.

In 2017, an SG100 Cloud Computer was launched to the ISS as part of OA-7 mission. It was manufactured by NCSIST of Taiwan and designed in collaboration with Academia Sinica, and National Central University under contract for NASA.

Operations

Expeditions

Each permanent crew is given an expedition number. Expeditions run up to six months, from launch until undocking, an 'increment' covers the same time period, but includes cargo spacecraft and all activities. Expeditions 1 to 6 consisted of three-person crews. Expeditions 7 to 12 were reduced to the safe minimum of two following the destruction of the NASA Shuttle Columbia. From Expedition 13 the crew gradually increased to six around 2010. With the arrival of crew on US commercial vehicles beginning in 2020, NASA has indicated that expedition size may be increased to seven crew members, the number ISS was originally designed for.

Gennady Padalka, member of Expeditions 9, 19/20, 31/32, and 43/44, and Commander of Expedition 11, has spent more time in space than anyone else, a total of 878 days, 11 hours, and 29 minutes. Peggy Whitson has spent the most time in space of any American, totalling 665 days, 22 hours, and 22 minutes during her time on Expeditions 5, 16, and 50/51/52.

Private flights

Travellers who pay for their own passage into space are termed spaceflight participants by Roscosmos and NASA, and are sometimes referred to as "space tourists", a term they generally dislike. All seven were transported to the ISS on Russian Soyuz spacecraft. When professional crews change over in numbers not divisible by the three seats in a Soyuz, and a short-stay crewmember is not sent, the spare seat is sold by MirCorp through Space Adventures. When the Space Shuttle was retired in 2011, and the station's crew size was reduced to six, space tourism was halted, as the partners relied on Russian transport seats for access to the station. Soyuz flight schedules increase after 2013, allowing five Soyuz flights (15 seats) with only two expeditions (12 seats) required. The remaining seats are sold for around US$40 million to members of the public who can pass a medical exam. ESA and NASA criticised private spaceflight at the beginning of the ISS, and NASA initially resisted training Dennis Tito, the first person to pay for his own passage to the ISS.

Anousheh Ansari became the first Iranian in space and the first self-funded woman to fly to the station. Officials reported that her education and experience make her much more than a tourist, and her performance in training had been "excellent." Ansari herself dismisses the idea that she is a tourist. She did Russian and European studies involving medicine and microbiology during her 10-day stay. The 2009 documentary Space Tourists follows her journey to the station, where she fulfilled "an age-old dream of man: to leave our planet as a "normal person" and travel into outer space."

In 2008, spaceflight participant Richard Garriott placed a geocache aboard the ISS during his flight. This is currently the only non-terrestrial geocache in existence. At the same time, the Immortality Drive, an electronic record of eight digitised human DNA sequences, was placed aboard the ISS.

Fleet operations

A wide variety of crewed and uncrewed spacecraft have supported the station's activities. Flights to the ISS include 37 Space Shuttle missions, 75 Progress resupply spacecraft (including the modified M-MIM2 and M-SO1 module transports), 59 crewed Soyuz spacecraft, 5 European ATVs, 9 Japanese HTVs, 20 SpaceX Dragon and 13 Cygnus missions.[citation needed]

There are currently 8 available docking ports for visiting spacecrafts:

- Harmony forward (with PMA 2 / IDA 2)
- Harmony zenith (with PMA 3 / IDA 3)
- Harmony nadir
- Unity nadir
- Pirs nadir
- Poisk zenith
- Rassvet nadir
- Zvezda aft

Crewed

As of 25 November 2020, 242 people from 19 countries had visited the space station, many of them multiple times. The United States sent 152 people, Russia sent 49, nine were Japanese, eight were Canadian, five were Italian, four were

French, three were German, and there were one each from Belgium, Brazil, Denmark, Great Britain, Kazakhstan, Malaysia, the Netherlands, South Africa, South Korea, Spain, Sweden and the United Arab Emirates.

Uncrewed

Uncrewed spaceflights to the International Space Station (ISS) are made primarily to deliver cargo, however several Russian modules have also docked to the outpost following uncrewed launches. Resupply missions typically use the Russian Progress spacecraft, European ATVs, Japanese Kounotori vehicles, and the American Dragon and Cygnus spacecraft. The primary docking system for Progress spacecraft is the automated Kurs system, with the manual TORU system as a backup. ATVs also use Kurs, however they are not equipped with TORU. Progress and ATV can remain docked for up to six months. The other spacecraft – the Japanese HTV, the SpaceX Dragon (under CRS phase 1) and the Northrop Grumman Cygnus – rendezvous with the station before being grappled using Canadarm2 and berthed at the nadir port of the Harmony or Unity module for one to two months. Under CRS phase 2, Cargo Dragon will dock autonomously at IDA-2 or 3 as the case may be. As of December 2020, Progress spacecraft have flown most of the uncrewed missions to the ISS.

Docking

All Russian spacecraft and self-propelled modules are able to rendezvous and dock to the space station without human intervention using the Kurs radar docking system from over 200 kilometres away. The European ATV uses star sensors and GPS to determine its intercept course. When it catches up it uses laser equipment to optically recognise Zvezda, along with the Kurs system for redundancy. Crew supervise these craft, but do not intervene except to send abort commands in emergencies. Progress and ATV supply craft can remain at the ISS for six months, allowing great flexibility in crew time for loading and unloading of supplies and trash.

From the initial station programs, the Russians pursued an automated docking methodology that used the crew in override or monitoring roles. Although the initial development costs were high, the system has become very reliable with standardisations that provide significant cost benefits in repetitive operations.

Soyuz spacecraft used for crew rotation also serve as lifeboats for emergency evacuation; they are replaced every six months and were used after the Columbia disaster to return stranded crew from the ISS. Expeditions require, on average, 2,722 kg of supplies, and as of 9 March 2011, crews had consumed a total of around 22,000 meals. Soyuz crew rotation flights and Progress resupply flights visit the station on average two and three times respectively each year.

Other vehicles berth instead of docking. The Japanese H-II Transfer Vehicle parks itself in progressively closer orbits to the station, and then awaits 'approach' commands from the crew, until it is close enough for a robotic arm to grapple and berth the vehicle to the USOS. Berthed craft can transfer International Standard Payload Racks. Japanese spacecraft berth for one to two months. The berthing Cygnus and SpaceX Dragon were contracted to fly cargo to the station under the phase 1 of the Commercial Resupply Services program.

From 26 February 2011 to 7 March 2011 four of the governmental partners (United States, ESA, Japan and Russia) had their spacecraft (NASA Shuttle, ATV, HTV, Progress and Soyuz) docked at the ISS, the only time this has happened to date. On 25 May 2012, SpaceX delivered the first commercial cargo with a Dragon spacecraft.

Launch and docking windows

Prior to a spacecraft's docking to the ISS, navigation and attitude control (GNC) is handed over to the ground control of the spacecraft's country of origin. GNC is set to allow the station to drift in space, rather than fire its thrusters or turn using gyroscopes. The solar panels of the station are turned edge-on to the incoming spacecraft, so residue from its thrusters does not damage the cells. Before its retirement, Shuttle launches were often given priority over Soyuz, with occasional priority given to Soyuz arrivals carrying crew and time-critical cargoes, such as biological experiment materials.

Repairs

Orbital Replacement Units (ORUs) are spare parts that can be readily replaced when a unit either passes its design life or fails. Examples of ORUs are pumps, storage tanks, controller boxes, antennas, and battery units. Some units can be replaced using robotic arms. Most are stored outside the station, either on small pallets called ExPRESS Logistics Carriers (ELCs) or share larger platforms called External Stowage Platforms which also hold science experiments. Both kinds of pallets provide electricity for many parts that could be damaged by the cold of space and require heating. The larger logistics carriers also have local area network (LAN) connections for telemetry to connect experiments. A heavy emphasis on stocking the USOS with ORU's occurred around 2011, before the end of the NASA shuttle programme, as its commercial replacements, Cygnus and Dragon, carry one tenth to one quarter the payload.

Unexpected problems and failures have impacted the station's assembly time-line and work schedules leading to periods of reduced capabilities and, in some cases, could have forced abandonment of the station for safety reasons. Serious problems include an air leak from the USOS in 2004, the venting of fumes from an Elektron oxygen generator in 2006, and the failure of the computers in the ROS in 2007 during STS-117 that left the station without thruster, Elektron, Vozdukh and other environmental control system operations. In the latter case, the root cause was found to be condensation inside electrical connectors leading to a short circuit.

During STS-120 in 2007 and following the relocation of the P6 truss and solar arrays, it was noted during unfurling that the solar array had torn and was not deploying properly. An EVA was carried out by Scott Parazynski, assisted by Douglas Wheelock. Extra precautions were taken to reduce the risk of electric shock, as the repairs were carried out with the solar array exposed to sunlight. The issues with the array were followed in the same year by problems with the starboard Solar Alpha Rotary Joint (SARJ), which rotates the arrays on the starboard side of the station. Excessive vibration and high-current spikes in the array drive motor were noted, resulting in a decision to substantially curtail motion of the starboard SARJ until the cause was understood. Inspections during EVAs on STS-120 and STS-123 showed extensive contamination from metallic shavings and debris in the large drive gear and confirmed damage to the large

metallic bearing surfaces, so the joint was locked to prevent further damage. Repairs to the joints were carried out during STS-126 with lubrication and the replacement of 11 out of 12 trundle bearings on the joint.

In September 2008, damage to the S1 radiator was first noticed in Soyuz imagery. The problem was initially not thought to be serious. The imagery showed that the surface of one sub-panel has peeled back from the underlying central structure, possibly because of micro-meteoroid or debris impact. On 15 May 2009 the damaged radiator panel's ammonia tubing was mechanically shut off from the rest of the cooling system by the computer-controlled closure of a valve. The same valve was then used to vent the ammonia from the damaged panel, eliminating the possibility of an ammonia leak. It is also known that a Service Module thruster cover struck the S1 radiator after being jettisoned during an EVA in 2008, but its effect, if any, has not been determined.

In the early hours of 1 August 2010, a failure in cooling Loop A (starboard side), one of two external cooling loops, left the station with only half of its normal cooling capacity and zero redundancy in some systems. The problem appeared to be in the ammonia pump module that circulates the ammonia cooling fluid. Several subsystems, including two of the four CMGs, were shut down.

Planned operations on the ISS were interrupted through a series of EVAs to address the cooling system issue. A first EVA on 7 August 2010, to replace the failed pump module, was not fully completed because of an ammonia leak in one of four quick-disconnects. A second EVA on 11 August successfully removed the failed pump module. A third EVA was required to restore Loop A to normal functionality.

The USOS's cooling system is largely built by the US company Boeing, which is also the manufacturer of the failed pump.

The four Main Bus Switching Units (MBSUs, located in the S0 truss), control the routing of power from the four solar array wings to the rest of the ISS. Each MBSU has two power channels that feed 160V DC from the arrays to two DC-to-DC power converters (DDCUs) that supply the 124V power used in the station. In late 2011 MBSU-1 ceased responding to commands or sending data confirming its health. While still routing power correctly, it was scheduled to be swapped out at the next available EVA. A spare MBSU was already on board, but a 30 August 2012 EVA failed to be completed when a bolt being tightened to finish installation of the spare unit jammed before the electrical connection was secured. The loss of MBSU-1 limited the station to 75% of its normal power capacity, requiring minor limitations in normal operations until the problem could be addressed.

On 5 September 2012, in a second six-hour EVA, astronauts Sunita Williams and Akihiko Hoshide successfully replaced MBSU-1 and restored the ISS to 100% power.

On 24 December 2013, astronauts installed a new ammonia pump for the station's cooling system. The faulty cooling system had failed earlier in the month, halting many of the station's science experiments. Astronauts had to brave a "mini blizzard" of ammonia while installing the new pump. It was only the second Christmas Eve spacewalk in NASA history.

Mission control centres

The components of the ISS are operated and monitored by their respective space agencies at mission control centres across the globe, including RKA Mission Control Center, ATV Control Centre, JEM Control Center and HTV Control Center at Tsukuba Space Center, Christopher C. Kraft Jr. Mission Control Center, Payload Operations and Integration Center, Columbus Control Center and Mobile Servicing System Control.

Life aboard

Crew activities

A typical day for the crew begins with a wake-up at 06:00, followed by post-sleep activities and a morning inspection of the station. The crew then eats breakfast and takes part in a daily planning conference with Mission Control before starting work at around 08:10. The first scheduled exercise of the day follows, after which the crew continues work until 13:05. Following a one-hour lunch break, the afternoon consists of more exercise and work before the crew carries out its pre-sleep activities beginning at 19:30, including dinner and a crew conference. The scheduled sleep period begins at 21:30. In general, the crew works ten hours per day on a weekday, and five hours on Saturdays, with the rest of the time their own for relaxation or work catch-up.

The time zone used aboard the ISS is Coordinated Universal Time (UTC). The windows are covered during night hours to give the impression of darkness because the station experiences 16 sunrises and sunsets per day. During visiting Space Shuttle missions, the ISS crew mostly follows the shuttle's Mission Elapsed Time (MET), which is a flexible time zone based on the launch time of the Space Shuttle mission.

The station provides crew quarters for each member of the expedition's crew, with two 'sleep stations' in the Zvezda and four more installed in Harmony. The USOS quarters are private, approximately person-sized soundproof booths. The ROS crew quarters include a small window, but provide less ventilation and sound proofing. A crew member can sleep in a crew quarter in a tethered sleeping bag, listen to music, use a laptop, and store personal items in a large drawer or in nets attached to the module's walls. The module also provides a reading lamp, a shelf and a desktop. Visiting crews have no allocated sleep module, and attach a sleeping bag to an available space on a wall. It is possible to sleep floating freely through the station, but this is generally avoided because of the possibility of bumping into sensitive equipment. It is important that crew accommodations be well ventilated; otherwise, astronauts can wake up oxygen-deprived and gasping for air, because a bubble of their own exhaled carbon dioxide has formed around their heads. During various station activities and crew rest times, the lights in the ISS can be dimmed, switched off, and colour temperatures adjusted.

Food and personal hygiene

On the USOS, most of the food aboard is vacuum sealed in plastic bags; cans are rare because they are heavy and expensive to transport. Preserved food is not highly regarded by the crew and taste is reduced in microgravity, so efforts are taken to make the food more palatable, including using more spices than in

regular cooking. The crew looks forward to the arrival of any spacecraft from Earth as they bring fresh fruit and vegetables. Care is taken that foods do not create crumbs, and liquid condiments are preferred over solid to avoid contaminating station equipment. Each crew member has individual food packages and cooks them using the on-board galley. The galley features two food warmers, a refrigerator (added in November 2008), and a water dispenser that provides both heated and unheated water. Drinks are provided as dehydrated powder that is mixed with water before consumption. Drinks and soups are sipped from plastic bags with straws, while solid food is eaten with a knife and fork attached to a tray with magnets to prevent them from floating away. Any food that floats away, including crumbs, must be collected to prevent it from clogging the station's air filters and other equipment.

Showers on space stations were introduced in the early 1970s on Skylab and Salyut 3.:139 By Salyut 6, in the early 1980s, the crew complained of the complexity of showering in space, which was a monthly activity. The ISS does not feature a shower; instead, crewmembers wash using a water jet and wet wipes, with soap dispensed from a toothpaste tube-like container. Crews are also provided with rinseless shampoo and edible toothpaste to save water.

There are two space toilets on the ISS, both of Russian design, located in Zvezda and Tranquility. These Waste and Hygiene Compartments use a fan-driven suction system similar to the Space Shuttle Waste Collection System. Astronauts first fasten themselves to the toilet seat, which is equipped with spring-loaded restraining bars to ensure a good seal. A lever operates a powerful fan and a suction hole slides open: the air stream carries the waste away. Solid waste is collected in individual bags which are stored in an aluminium container. Full containers are transferred to Progress spacecraft for disposal. Liquid waste is evacuated by a hose connected to the front of the toilet, with anatomically correct "urine funnel adapters" attached to the tube so that men and women can use the same toilet. The diverted urine is collected and transferred to the Water Recovery System, where it is recycled into drinking water.

Crew health and safety

Overall

On 12 April 2019, NASA reported medical results from the Astronaut Twin Study. Astronaut Scott Kelly spent a year in space on the ISS, while his twin spent the year on Earth. Several long-lasting changes were observed, including those related to alterations in DNA and cognition, when one twin was compared with the other.

In November 2019, researchers reported that astronauts experienced serious blood flow and clot problems while on board the ISS, based on a six-month study of 11 healthy astronauts. The results may influence long-term spaceflight, including a mission to the planet Mars, according to the researchers.

Radiation

The ISS is partially protected from the space environment by Earth's magnetic field. From an average distance of about 70,000 km (43,000 mi) from the Earth's surface, depending on Solar activity, the magnetosphere begins to deflect solar wind around Earth and the space station. Solar flares are still a hazard to the

crew, who may receive only a few minutes warning. In 2005, during the initial "proton storm" of an X-3 class solar flare, the crew of Expedition 10 took shelter in a more heavily shielded part of the ROS designed for this purpose.

Subatomic charged particles, primarily protons from cosmic rays and solar wind, are normally absorbed by Earth's atmosphere. When they interact in sufficient quantity, their effect is visible to the naked eye in a phenomenon called an aurora. Outside Earth's atmosphere, ISS crews are exposed to approximately one millisievert each day (about a year's worth of natural exposure on Earth), resulting in a higher risk of cancer. Radiation can penetrate living tissue and damage the DNA and chromosomes of lymphocytes; being central to the immune system, any damage to these cells could contribute to the lower immunity experienced by astronauts. Radiation has also been linked to a higher incidence of cataracts in astronauts. Protective shielding and medications may lower the risks to an acceptable level.

Radiation levels on the ISS are about five times greater than those experienced by airline passengers and crew, as Earth's electromagnetic field provides almost the same level of protection against solar and other types of radiation in low Earth orbit as in the stratosphere. For example, on a 12-hour flight, an airline passenger would experience 0.1 millisieverts of radiation, or a rate of 0.2 millisieverts per day; this is only one fifth the rate experienced by an astronaut in LEO. Additionally, airline passengers experience this level of radiation for a few hours of flight, while the ISS crew are exposed for their whole stay on board the station.

Stress

There is considerable evidence that psychosocial stressors are among the most important impediments to optimal crew morale and performance. Cosmonaut Valery Ryumin wrote in his journal during a particularly difficult period on board the Salyut 6 space station: "All the conditions necessary for murder are met if you shut two men in a cabin measuring 18 feet by 20 and leave them together for two months."

NASA's interest in psychological stress caused by space travel, initially studied when their crewed missions began, was rekindled when astronauts joined cosmonauts on the Russian space station Mir. Common sources of stress in early US missions included maintaining high performance under public scrutiny and isolation from peers and family. The latter is still often a cause of stress on the ISS, such as when the mother of NASA Astronaut Daniel Tani died in a car accident, and when Michael Fincke was forced to miss the birth of his second child.

A study of the longest spaceflight concluded that the first three weeks are a critical period where attention is adversely affected because of the demand to adjust to the extreme change of environment. ISS crew flights typically last about five to six months.

The ISS working environment includes further stress caused by living and working in cramped conditions with people from very different cultures who speak a different language. First-generation space stations had crews who spoke a single language; second- and third-generation stations have crew from many cultures who speak many languages. Astronauts must speak English and Russian, and knowing

additional languages is even better.

Due to the lack of gravity, confusion often occurs. Even though there is no up and down in space, some crew members feel like they are oriented upside down. They may also have difficulty measuring distances. This can cause problems like getting lost inside the space station, pulling switches in the wrong direction or misjudging the speed of an approaching vehicle during docking.

Medical

The physiological effects of long-term weightlessness include muscle atrophy, deterioration of the skeleton (osteopenia), fluid redistribution, a slowing of the cardiovascular system, decreased production of red blood cells, balance disorders, and a weakening of the immune system. Lesser symptoms include loss of body mass, and puffiness of the face.

Sleep is regularly disturbed on the ISS because of mission demands, such as incoming or departing spacecraft. Sound levels in the station are unavoidably high. The atmosphere is unable to thermosiphon naturally, so fans are required at all times to process the air which would stagnate in the freefall (zero-G) environment.

To prevent some of the adverse effects on the body, the station is equipped with: two TVIS treadmills (including the COLBERT); the ARED (Advanced Resistive Exercise Device), which enables various weightlifting exercises that add muscle without raising (or compensating for) the astronauts' reduced bone density; and a stationary bicycle. Each astronaut spends at least two hours per day exercising on the equipment. Astronauts use bungee cords to strap themselves to the treadmill.

Microbiological environmental hazards

Hazardous moulds that can foul air and water filters may develop aboard space stations. They can produce acids that degrade metal, glass, and rubber. They can also be harmful to the crew's health. Microbiological hazards have led to a development of the LOCAD-PTS which identifies common bacteria and moulds faster than standard methods of culturing, which may require a sample to be sent back to Earth. Researchers in 2018 reported, after detecting the presence of five Enterobacter bugandensis bacterial strains on the ISS (none of which are pathogenic to humans), that microorganisms on the ISS should be carefully monitored to continue assuring a medically healthy environment for astronauts.

Contamination on space stations can be prevented by reduced humidity, and by using paint that contains mould-killing chemicals, as well as the use of antiseptic solutions. All materials used in the ISS are tested for resistance against fungi.

In April 2019, NASA reported that a comprehensive study had been conducted into the microorganisms and fungi present on the ISS. The results may be useful in improving the health and safety conditions for astronauts.

Noise

Space flight is not inherently quiet, with noise levels exceeding acoustic

standards as far back as the Apollo missions. For this reason, NASA and the International Space Station international partners have developed noise control and hearing loss prevention goals as part of the health program for crew members. Specifically, these goals have been the primary focus of the ISS Multilateral Medical Operations Panel (MMOP) Acoustics Subgroup since the first days of ISS assembly and operations. The effort includes contributions from acoustical engineers, audiologists, industrial hygienists, and physicians who comprise the subgroup's membership from NASA, the Russian Space Agency (RSA), the European Space Agency (ESA), the Japanese Aerospace Exploration Agency (JAXA), and the Canadian Space Agency (CSA).

When compared to terrestrial environments, the noise levels incurred by astronauts and cosmonauts on the ISS may seem insignificant and typically occur at levels that would not be of major concern to the Occupational Safety and Health Administration – rarely reaching 85 dBA. But crew members are exposed to these levels 24 hours a day, seven days a week, with current missions averaging six months in duration. These levels of noise also impose risks to crew health and performance in the form of sleep interference and communication, as well as reduced alarm audibility.

Over the 19 plus year history of the ISS, significant efforts have been put forth to limit and reduce noise levels on the ISS. During design and pre-flight activities, members of the Acoustic Subgroup have written acoustic limits and verification requirements, consulted to design and choose quietest available payloads, and then conducted acoustic verification tests prior to launch.:5.7.3 During spaceflights, the Acoustics Subgroup has assessed each ISS module's in flight sound levels, produced by a large number of vehicle and science experiment noise sources, to assure compliance with strict acoustic standards. The acoustic environment on ISS changed when additional modules were added during its construction, and as additional spacecraft arrive at the ISS. The Acoustics Subgroup has responded to this dynamic operations schedule by successfully designing and employing acoustic covers, absorptive materials, noise barriers, and vibration isolators to reduce noise levels. Moreover, when pumps, fans, and ventilation systems age and show increased noise levels, this Acoustics Subgroup has guided ISS managers to replace the older, noisier instruments with quiet fan and pump technologies, significantly reducing ambient noise levels.

NASA has adopted most-conservative damage risk criteria (based on recommendations from the National Institute for Occupational Safety and Health and the World Health Organization), in order to protect all crew members. The MMOP Acoustics Subgroup has adjusted its approach to managing noise risks in this unique environment by applying, or modifying, terrestrial approaches for hearing loss prevention to set these conservative limits. One innovative approach has been NASA's Noise Exposure Estimation Tool (NEET), in which noise exposures are calculated in a task-based approach to determine the need for hearing protection devices (HPDs). Guidance for use of HPDs, either mandatory use or recommended, is then documented in the Noise Hazard Inventory, and posted for crew reference during their missions. The Acoustics Subgroup also tracks spacecraft noise exceedances, applies engineering controls, and recommends hearing protective devices to reduce crew noise exposures. Finally, hearing thresholds are monitored on-orbit, during missions.

There have been no persistent mission-related hearing threshold shifts among US

Orbital Segment crewmembers (JAXA, CSA, ESA, NASA) during what is approaching 20 years of ISS mission operations, or nearly 175,000 work hours. In 2020, the MMOP Acoustics Subgroup received the Safe-In-Sound Award for Innovation for their combined efforts to mitigate any health effects of noise.

Fire and toxic gases

An onboard fire or a toxic gas leak are other potential hazards. Ammonia is used in the external radiators of the station and could potentially leak into the pressurised modules.

Orbit

The ISS is currently maintained in a nearly circular orbit with a minimum mean altitude of 370 km (230 mi) and a maximum of 460 km (290 mi), in the centre of the thermosphere, at an inclination of 51.6 degrees to Earth's equator. This orbit was selected because it is the lowest inclination that can be directly reached by Russian Soyuz and Progress spacecraft launched from Baikonur Cosmodrome at 46° N latitude without overflying China or dropping spent rocket stages in inhabited areas. It travels at an average speed of 28,000 kilometres per hour (17,000 mph), and completes 15.5 orbits per day (93 minutes per orbit). The station's altitude was allowed to fall around the time of each NASA shuttle flight to permit heavier loads to be transferred to the station. After the retirement of the shuttle, the nominal orbit of the space station was raised in altitude (from about 350 km to about 400 km). Other, more frequent supply spacecraft do not require this adjustment as they are substantially higher performance vehicles.

Atmospheric drag reduces the altitude by about 2 km a month on average. Orbital boosting can be performed by the station's two main engines on the Zvezda service module, or Russian or European spacecraft docked to Zvezda's aft port. The Automated Transfer Vehicle is constructed with the possibility of adding a second docking port to its aft end, allowing other craft to dock and boost the station. It takes approximately two orbits (three hours) for the boost to a higher altitude to be completed. Maintaining ISS altitude uses about 7.5 tonnes of chemical fuel per annum at an annual cost of about $210 million.

The Russian Orbital Segment contains the Data Management System, which handles Guidance, Navigation and Control (ROS GNC) for the entire station. Initially, Zarya, the first module of the station, controlled the station until a short time after the Russian service module Zvezda docked and was transferred control. Zvezda contains the ESA built DMS-R Data Management System. Using two fault-tolerant computers (FTC), Zvezda computes the station's position and orbital trajectory using redundant Earth horizon sensors, Solar horizon sensors as well as Sun and star trackers. The FTCs each contain three identical processing units working in parallel and provide advanced fault-masking by majority voting.

Orientation

Zvezda uses gyroscopes (reaction wheels) and thrusters to turn itself around. Gyroscopes do not require propellant; instead they use electricity to 'store'

momentum in flywheels by turning in the opposite direction to the station's movement. The USOS has its own computer-controlled gyroscopes to handle its extra mass. When gyroscopes 'saturate', thrusters are used to cancel out the stored momentum. In February 2005, during Expedition 10, an incorrect command was sent to the station's computer, using about 14 kilograms of propellant before the fault was noticed and fixed. When attitude control computers in the ROS and USOS fail to communicate properly, this can result in a rare 'force fight' where the ROS GNC computer must ignore the USOS counterpart, which itself has no thrusters.

Docked spacecraft can also be used to maintain station attitude, such as for troubleshooting or during the installation of the S3/S4 truss, which provides electrical power and data interfaces for the station's electronics.

Orbital debris threats

The low altitudes at which the ISS orbits are also home to a variety of space debris, including spent rocket stages, defunct satellites, explosion fragments (including materials from anti-satellite weapon tests), paint flakes, slag from solid rocket motors, and coolant released by US-A nuclear-powered satellites. These objects, in addition to natural micrometeoroids, are a significant threat. Objects large enough to destroy the station can be tracked, and are not as dangerous as smaller debris. Objects too small to be detected by optical and radar instruments, from approximately 1 cm down to microscopic size, number in the trillions. Despite their small size, some of these objects are a threat because of their kinetic energy and direction in relation to the station. Spacewalking crew in spacesuits are also at risk of suit damage and consequent exposure to vacuum.

Ballistic panels, also called micrometeorite shielding, are incorporated into the station to protect pressurised sections and critical systems. The type and thickness of these panels depend on their predicted exposure to damage. The station's shields and structure have different designs on the ROS and the USOS. On the USOS, Whipple Shields are used. The US segment modules consist of an inner layer made from 1.5–5.0 cm-thick (0.59–1.97 in) aluminium, a 10 cm-thick (3.9 in) intermediate layers of Kevlar and Nextel, and an outer layer of stainless steel, which causes objects to shatter into a cloud before hitting the hull, thereby spreading the energy of impact. On the ROS, a carbon fibre reinforced polymer honeycomb screen is spaced from the hull, an aluminium honeycomb screen is spaced from that, with a screen-vacuum thermal insulation covering, and glass cloth over the top.

Space debris is tracked remotely from the ground, and the station crew can be notified. If necessary, thrusters on the Russian Orbital Segment can alter the station's orbital altitude, avoiding the debris. These Debris Avoidance Manoeuvres (DAMs) are not uncommon, taking place if computational models show the debris will approach within a certain threat distance. Ten DAMs had been performed by the end of 2009. Usually, an increase in orbital velocity of the order of 1 m/s is used to raise the orbit by one or two kilometres. If necessary, the altitude can also be lowered, although such a manoeuvre wastes propellant. If a threat from orbital debris is identified too late for a DAM to be safely conducted, the station crew close all the hatches aboard the station and retreat into their Soyuz spacecraft in order to be able to evacuate in the event the station was seriously damaged by the debris. This partial station

evacuation has occurred on 13 March 2009, 28 June 2011, 24 March 2012 and 16 June 2015.

Sightings from Earth

Naked-eye visibility

The ISS is visible to the naked eye as a slow-moving, bright white dot because of reflected sunlight, and can be seen in the hours after sunset and before sunrise, when the station remains sunlit but the ground and sky are dark. The ISS takes about 10 minutes to pass from one horizon to another, and will only be visible part of that time because of moving into or out of the Earth's shadow. Because of the size of its reflective surface area, the ISS is the brightest artificial object in the sky (excluding other satellite flares), with an approximate maximum magnitude of −4 when overhead (similar to Venus). The ISS, like many satellites including the Iridium constellation, can also produce flares of up to 16 times the brightness of Venus as sunlight glints off reflective surfaces. The ISS is also visible in broad daylight, albeit with a great deal more difficulty.

Tools are provided by a number of websites such as Heavens-Above (see Live viewing below) as well as smartphone applications that use orbital data and the observer's longitude and latitude to indicate when the ISS will be visible (weather permitting), where the station will appear to rise, the altitude above the horizon it will reach and the duration of the pass before the station disappears either by setting below the horizon or entering into Earth's shadow.

In November 2012 NASA launched its "Spot the Station" service, which sends people text and email alerts when the station is due to fly above their town. The station is visible from 95% of the inhabited land on Earth, but is not visible from extreme northern or southern latitudes.

Under specific conditions, the ISS can be observed at night on 5 consecutive orbits. Those conditions are 1) a mid-latitude observer location, 2) near the time of the solstice with 3) the ISS passing in the direction of the pole from the observer near midnight local time. The three photos show the first, middle and last of the five passes on June 5/6, 2014.

Astrophotography

Using a telescope-mounted camera to photograph the station is a popular hobby for astronomers, while using a mounted camera to photograph the Earth and stars is a popular hobby for crew. The use of a telescope or binoculars allows viewing of the ISS during daylight hours.

Some amateur astronomers also use telescopic lenses to photograph the ISS while it transits the Sun, sometimes doing so during an eclipse (and so the Sun, Moon, and ISS are all positioned approximately in a single line). One example is during the 21 August solar eclipse, where at one location in Wyoming, images of the ISS were captured during the eclipse. Similar images were captured by NASA from a location in Washington.

Parisian engineer and astrophotographer Thierry Legault, known for his photos of spaceships transiting the Sun, travelled to Oman in 2011 to photograph the Sun,

Moon and space station all lined up. Legault, who received the Marius Jacquemetton award from the Société astronomique de France in 1999, and other hobbyists, use websites that predict when the ISS will transit the Sun or Moon and from what location those passes will be visible.

End of mission

According to the Outer Space Treaty, the United States and Russia are legally responsible for all modules they have launched. Several possible disposal options were considered: Natural orbital decay with random reentry (as with Skylab), boosting the station to a higher altitude (which would delay reentry), and a controlled targeted de-orbit to a remote ocean area. As of late 2010, the preferred plan is to use a slightly modified Progress spacecraft to de-orbit the ISS. This plan was seen as the simplest, cheapest and with the highest margin.

OPSEK was previously intended to be constructed of modules from the Russian Orbital Segment after the ISS is decommissioned. The modules under consideration for removal from the current ISS included the Multipurpose Laboratory Module (Nauka), planned to be launched in spring 2021 as of May 2020, and the other new Russian modules that are proposed to be attached to Nauka. These newly launched modules would still be well within their useful lives in 2024.

At the end of 2011, the Exploration Gateway Platform concept also proposed using leftover USOS hardware and Zvezda 2 as a refuelling depot and service station located at one of the Earth-Moon Lagrange points. However, the entire USOS was not designed for disassembly and will be discarded.

In February 2015, Roscosmos announced that it would remain a part of the ISS programme until 2024. Nine months earlier—in response to US sanctions against Russia over the annexation of Crimea—Russian Deputy Prime Minister Dmitry Rogozin had stated that Russia would reject a US request to prolong the orbiting station's use beyond 2020, and would only supply rocket engines to the US for non-military satellite launches.

On 28 March 2015, Russian sources announced that Roscosmos and NASA had agreed to collaborate on the development of a replacement for the current ISS. Igor Komarov, the head of Russia's Roscosmos, made the announcement with NASA administrator Charles Bolden at his side. In a statement provided to SpaceNews on 28 March, NASA spokesman David Weaver said the agency appreciated the Russian commitment to extending the ISS, but did not confirm any plans for a future space station.

On 30 September 2015, Boeing's contract with NASA as prime contractor for the ISS was extended to 30 September 2020. Part of Boeing's services under the contract will relate to extending the station's primary structural hardware past 2020 to the end of 2028.

There have also been suggestions that the station could be converted to commercial operations after it is retired by government entities.

In July 2018, the Space Frontier Act of 2018 was intended to extend operations of the ISS to 2030. This bill was unanimously approved in the Senate, but failed

to pass in the U.S. House. In September 2018, the Leading Human Spaceflight Act was introduced with the intent to extend operations of the ISS to 2030, and was confirmed in December 2018.

Cost

The ISS has been described as the most expensive single item ever constructed. As of 2010 the total cost was US$150 billion. This includes NASA's budget of $58.7 billion (inflation-unadjusted) for the station from 1985 to 2015 ($72.4 billion in 2010 dollars), Russia's $12 billion, Europe's $5 billion, Japan's $5 billion, Canada's $2 billion, and the cost of 36 shuttle flights to build the station, estimated at $1.4 billion each, or $50.4 billion in total. Assuming 20,000 person-days of use from 2000 to 2015 by two- to six-person crews, each person-day would cost $7.5 million, less than half the inflation-adjusted $19.6 million ($5.5 million before inflation) per person-day of Skylab.

Estimated time: 44 minutes
Source: https://en.wikipedia.org/wiki/International_Space_Station

C.3.3 Physical layer of Computer Networks

In this chapter we will look at the lowest layer in our protocol model, the physical layer. It defines the electrical, timing and other interfaces by which bits are sent as signals over channels. The physical layer is the foundation on which the network is built. The properties of different kinds of physical channels determine the performance (e.g., throughput, latency, and error rate) so it is a good place to start our journey into networkland.
We will begin with a theoretical analysis of data transmission, only to discover that Mother (Parent?) Nature puts some limits on what can be sent over a channel. Then we will cover three kinds of transmission media: guided (copper wire and fiber optics), wireless (terrestrial radio), and satellite. Each of these technologies has different properties that affect the design and performance of the networks that use them. This material will provide background information on the key transmission technologies used in modern networks.
Next comes digital modulation, which is all about how analog signals are converted into digital bits and back again. After that we will look at multiplexing schemes, exploring how multiple conversations can be put on the same transmission medium at the same time without interfering with one another.
Finally, we will look at three examples of communication systems used in practice for wide area computer networks: the (fixed) telephone system, the mobile phone system, and the cable television system. Each of these is important in practice, so we will devote a fair amount of space to each one.

2.1 THE THEORETICAL BASIS FOR DATA COMMUNICATION

Sorry! This chapter will be skiped. There are too many formula's I can't display in a simple txt document. Good luck with the rest of the text!
If you are Giuseppe: Sorry, it was just easier! Before choosing I skipped through it and it is probably the most embedded oriented stuff we will encounter during any research project ;-)

2.2 GUIDED TRANSMISSION MEDIA

The purpose of the physical layer is to transport bits from one machine to another. Various physical media can be used for the actual transmission. Each one has its own niche in terms of bandwidth, delay, cost, and ease of installation and maintenance. Media are roughly grouped into guided media, such as copper wire and fiber optics, and unguided media, such as terrestrial wireless, satellite, and lasers through the air. We will look at guided media in this section, and unguided media in the next sections.

2.2.1 Magnetic Media

One of the most common ways to transport data from one computer to another is to write them onto magnetic tape or removable media (e.g., recordable DVDs), physically transport the tape or disks to the destination machine, and read them back in again. Although this method is not as sophisticated as using a geosyn-chronous communication satellite, it is often more cost effective, especially for applications in which high bandwidth or cost per bit transported is the key factor.

A simple calculation will make this point clear. An industry-standard Ultrium tape can hold 800 gigabytes. A box 60 × 60 × 60 cm can hold about 1000 of these tapes, for a total capacity of 800 terabytes, or 6400 terabits (6.4 petabits). A box of tapes can be delivered anywhere in the United States in 24 hours by Federal Express and other companies. The effective bandwidth of this transmission is 6400 terabits/86,400 sec, or a bit over 70 Gbps. If the destination is only an hour away by road, the bandwidth is increased to over 1700 Gbps. No computer network can even approach this. Of course, networks are getting faster, but tape densities are increasing, too.

If we now look at cost, we get a similar picture. The cost of an Ultrium tape is around $40 when bought in bulk. A tape can be reused at least 10 times, so the tape cost is maybe $4000 per box per usage. Add to this another $1000 for shipping (probably much less), and we have a cost of roughly $5000 to ship 800 TB.

This amounts to shipping a gigabyte for a little over half a cent. No network can beat that. The moral of the story is:

Never underestimate the bandwidth of a station wagon full of tapes hurtling down the highway.

2.2.2 Twisted Pairs

Although the bandwidth characteristics of magnetic tape are excellent, the delay characteristics are poor. Transmission time is measured in minutes or hours, not milliseconds. For many applications an online connection is needed. One of the oldest and still most common transmission media is twisted pair. A twisted pair consists of two insulated copper wires, typically about 1 mm thick. The wires are twisted together in a helical form, just like a DNA molecule. Twisting is done because two parallel wires constitute a fine antenna. When the wires are twisted, the waves from different twists cancel out, so the wire radiates less effectively. A signal is usually carried as the difference in voltage between the two wires in the pair. This provides better immunity to external noise because the noise tends to affect both wires the same, leaving the differential unchanged.

The most common application of the twisted pair is the telephone system. Nearly all telephones are connected to the telephone company (telco) office by a twisted pair. Both telephone calls and ADSL Internet access run over these lines.

Twisted pairs can run several kilometers without amplification, but for longer distances the signal becomes too attenuated and repeaters are needed. When many twisted pairs run in parallel for a substantial distance, such as all the wires coming from an apartment building to the telephone company office, they are bundled together and encased in a protective sheath. The pairs in these bundles would interfere with one another if it were not for the twisting. In parts of the world where telephone lines run on poles above ground, it is common to see bundles several centimeters in diameter.

Twisted pairs can be used for transmitting either analog or digital information.

The bandwidth depends on the thickness of the wire and the distance traveled, but several megabits/sec can be achieved for a few kilometers in many cases. Due to their adequate performance and low cost, twisted pairs are widely used and are likely to remain so for years to come.

Twisted-pair cabling comes in several varieties. The garden variety deployed in many office buildings is called Category 5 cabling, or ‘‘Cat 5.’’ A category 5 twisted pair consists of two insulated wires gently twisted together. Four such

pairs are typically grouped in a plastic sheath to protect the wires and keep them together. This arrangement is shown in Fig. 2-3.
Different LAN standards may use the twisted pairs differently. For example, 100-Mbps Ethernet uses two (out of the four) pairs, one pair for each direction.

To reach higher speeds, 1-Gbps Ethernet uses all four pairs in both directions simultaneously; this requires the receiver to factor out the signal that is transmitted locally.
Some general terminology is now in order. Links that can be used in both directions at the same time, like a two-lane road, are called full-duplex links. In contrast, links that can be used in either direction, but only one way at a time, like a single-track railroad line. are called half-duplex links. A third category consists of links that allow traffic in only one direction, like a one-way street. They are called simplex links.
Returning to twisted pair, Cat 5 replaced earlier Category 3 cables with a similar cable that uses the same connector, but has more twists per meter. More twists result in less crosstalk and a better-quality signal over longer distances, making the cables more suitable for high-speed computer communication, especially 100-Mbps and 1-Gbps Ethernet LANs.
New wiring is more likely to be Category 6 or even Category 7. These categories has more stringent specifications to handle signals with greater bandwidths. Some cables in Category 6 and above are rated for signals of 500 MHz and can support the 10-Gbps links that will soon be deployed.
Through Category 6, these wiring types are referred to as UTP (Unshielded Twisted Pair) as they consist simply of wires and insulators. In contrast to these, Category 7 cables have shielding on the individual twisted pairs, as well as around the entire cable (but inside the plastic protective sheath). Shielding reduces the susceptibility to external interference and crosstalk with other nearby cables to meet demanding performance specifications. The cables are reminiscent of the high-quality, but bulky and expensive shielded twisted pair cables that IBM introduced in the early 1980s, but which did not prove popular outside of IBM installations. Evidently, it is time to try again.

2.2.3 Coaxial Cable

Another common transmission medium is the coaxial cable (known to its many friends as just ‘‘coax’’ and pronounced ‘‘co-ax’’). It has better shielding and greater bandwidth than unshielded twisted pairs, so it can span longer distances at higher speeds. Two kinds of coaxial cable are widely used. One kind, 50-ohm cable, is commonly used when it is intended for digital transmission from the start. The other kind, 75-ohm cable, is commonly used for analog transmission and cable television. This distinction is based on historical, rather than technical, factors (e.g., early dipole antennas had an impedance of 300 ohms, and it was easy to use existing 4:1 impedance-matching transformers). Starting in the mid-1990s, cable TV operators began to provide Internet access over cable, which has made 75-ohm cable more important for data communication.
A coaxial cable consists of a stiff copper wire as the core, surrounded by an insulating material. The insulator is encased by a cylindrical conductor, often as a closely woven braided mesh. The outer conductor is covered in a protective plastic sheath. A cutaway view of a coaxial cable is shown in Fig. 2-4.
The construction and shielding of the coaxial cable give it a good combination of high bandwidth and excellent noise immunity. The bandwidth possible depends on the cable quality and length. Modern cables have a bandwidth of up to a few GHz. Coaxial cables used to be widely used within the telephone system for

long-distance lines but have now largely been replaced by fiber optics on long-haul routes. Coax is still widely used for cable television and metropolitan area networks, however.

2.2.4 Power Lines

The telephone and cable television networks are not the only sources of wiring that can be reused for data communication. There is a yet more common kind of wiring: electrical power lines. Power lines deliver electrical power to houses, and electrical wiring within houses distributes the power to electrical outlets.

The use of power lines for data communication is an old idea. Power lines have been used by electricity companies for low-rate communication such as remote metering for many years, as well in the home to control devices (e.g., the X10 standard). In recent years there has been renewed interest in high-rate communication over these lines, both inside the home as a LAN and outside the home for broadband Internet access. We will concentrate on the most common scenario: using electrical wires inside the home.

The convenience of using power lines for networking should be clear. Simply plug a TV and a receiver into the wall, which you must do anyway because they need power, and they can send and receive movies over the electrical wiring. This configuration is shown in Fig. 2-5. There is no other plug or radio. The data signal is superimposed on the low-frequency power signal (on the active or ‘‘hot’’ wire) as both signals use the wiring at the same time.

The difficulty with using household electrical wiring for a network is that it was designed to distribute power signals. This task is quite different than distributing data signals, at which household wiring does a horrible job. Electrical signals are sent at 50–60 Hz and the wiring attenuates the much higher frequency (MHz) signals needed for high-rate data communication. The electrical properties of the wiring vary from one house to the next and change as appliances are turned on and off, which causes data signals to bounce around the wiring. Transient currents when appliances switch on and off create electrical noise over a wide range of frequencies. And without the careful twisting of twisted pairs, electrical wiring acts as a fine antenna, picking up external signals and radiating signals of its own.

This behavior means that to meet regulatory requirements, the data signal must exclude licensed frequencies such as the amateur radio bands.

Despite these difficulties, it is practical to send at least 100 Mbps over typical household electrical wiring by using communication schemes that resist impaired frequencies and bursts of errors. Many products use various proprietary standards for power-line networking, so international standards are actively under development.

2.2.5 Fiber Optics

Many people in the computer industry take enormous pride in how fast computer technology is improving as it follows Moore’s law, which predicts a doubling of the number of transistors per chip roughly every two years (Schaller, 1997). The original (1981) IBM PC ran at a clock speed of 4.77 MHz. Twenty-eight years later, PCs could run a four-core CPU at 3 GHz. This increase is a gain of a factor of around 2500, or 16 per decade. Impressive.

In the same period, wide area communication links went from 45 Mbps (a T3 line in the telephone system) to 100 Gbps (a modern long distance line). This gain is similarly impressive, more than a factor of 2000 and close to 16 per decade, while at the same time the error rate went from 10–5 per bit to almost zero. Furthermore, single CPUs are beginning to approach physical limits, which is why

it is now the number of CPUs that is being increased per chip. In contrast, the achievable bandwidth with fiber technology is in excess of 50,000 Gbps (50 Tbps) and we are nowhere near reaching these limits. The current practical limit of around 100 Gbps is due to our inability to convert between electrical and optical signals any faster. To build higher-capacity links, many channels are simply carried in parallel over a single fiber.

In this section we will study fiber optics to learn how that transmission technology works. In the ongoing race between computing and communication, communication may yet win because of fiber optic networks. The implication of this would be essentially infinite bandwidth and a new conventional wisdom that computers are hopelessly slow so that networks should try to avoid computation at all costs, no matter how much bandwidth that wastes. This change will take a while to sink in to a generation of computer scientists and engineers taught to think in terms of the low Shannon limits imposed by copper.

Of course, this scenario does not tell the whole story because it does not include cost. The cost to install fiber over the last mile to reach consumers and bypass the low bandwidth of wires and limited availability of spectrum is tremendous. It also costs more energy to move bits than to compute. We may always have islands of inequities where either computation or communication is essentially free. For example, at the edge of the Internet we throw computation and storage at the problem of compressing and caching content, all to make better use of Internet access links. Within the Internet, we may do the reverse, with companies such as Google moving huge amounts of data across the network to where it is cheaper to store or compute on it.

Fiber optics are used for long-haul transmission in network backbones, high-speed LANs (although so far, copper has always managed catch up eventually), and high-speed Internet access such as FttH (Fiber to the Home). An optical transmission system has three key components: the light source, the transmission medium, and the detector. Conventionally, a pulse of light indicates a 1 bit and the absence of light indicates a 0 bit. The transmission medium is an ultra-thin fiber of glass. The detector generates an electrical pulse when light falls on it. By attaching a light source to one end of an optical fiber and a detector to the other, we have a unidirectional data transmission system that accepts an electrical signal, converts and transmits it by light pulses, and then reconverts the output to an electrical signal at the receiving end.

This transmission system would leak light and be useless in practice were it not for an interesting principle of physics. When a light ray passes from one medium to another—for example, from fused silica to air—the ray is refracted (bent) at the silica/air boundary, as shown in Fig. 2-6(a). Here we see a light ray incident on the boundary at an angle $\alpha 1$ emerging at an angle $\beta 1$. The amount of refraction depends on the properties of the two media (in particular, their indices of refraction). For angles of incidence above a certain critical value, the light is refracted back into the silica; none of it escapes into the air. Thus, a light ray incident at or above the critical angle is trapped inside the fiber, as shown in Fig. 2-6(b), and can propagate for many kilometers with virtually no loss.

The sketch of Fig. 2-6(b) shows only one trapped ray, but since any light ray incident on the boundary above the critical angle will be reflected internally, many different rays will be bouncing around at different angles. Each ray is said to have a different mode, so a fiber having this property is called a multimode fiber.

However, if the fiber’s diameter is reduced to a few wavelengths of light the fiber acts like a wave guide and the light can propagate only in a straight

line, without bouncing, yielding a single-mode fiber. Single-mode fibers are more expensive but are widely used for longer distances. Currently available single-mode fibers can transmit data at 100 Gbps for 100 km without amplification. Even higher data rates have been achieved in the laboratory for shorter distances.

Transmission of Light Through Fiber

Optical fibers are made of glass, which, in turn, is made from sand, an inexpensive raw material available in unlimited amounts. Glassmaking was known to the ancient Egyptians, but their glass had to be no more than 1 mm thick or the light could not shine through. Glass transparent enough to be useful for windows was developed during the Renaissance. The glass used for modern optical fibers is so transparent that if the oceans were full of it instead of water, the seabed would be as visible from the surface as the ground is from an airplane on a clear day.

The attenuation of light through glass depends on the wavelength of the light (as well as on some physical properties of the glass). It is defined as the ratio of input to output signal power. For the kind of glass used in fibers, the attenuation is shown in Fig. 2-7 in units of decibels per linear kilometer of fiber. For example, a factor of two loss of signal power gives an attenuation of $10 \log_{10} 2 = 3$ dB.

The figure shows the near-infrared part of the spectrum, which is what is used in practice. Visible light has slightly shorter wavelengths, from 0.4 to 0.7 microns.

(1 micron is 10–6 meters.) The true metric purist would refer to these wavelengths as 400 nm to 700 nm, but we will stick with traditional usage.

Three wavelength bands are most commonly used at present for optical communication. They are centered at 0.85, 1.30, and 1.55 microns, respectively. All three bands are 25,000 to 30,000 GHz wide. The 0.85-micron band was used first.

It has higher attenuation and so is used for shorter distances, but at that wavelength the lasers and electronics could be made from the same material (gallium arsenide). The last two bands have good attenuation properties (less than 5% loss per kilometer). The 1.55-micron band is now widely used with erbium-doped amplifiers that work directly in the optical domain.

Light pulses sent down a fiber spread out in length as they propagate. This spreading is called chromatic dispersion. The amount of it is wavelength dependent. One way to keep these spread-out pulses from overlapping is to increase the distance between them, but this can be done only by reducing the signaling rate.

Fortunately, it has been discovered that making the pulses in a special shape related to the reciprocal of the hyperbolic cosine causes nearly all the dispersion effects cancel out, so it is possible to send pulses for thousands of kilometers without appreciable shape distortion. These pulses are called solitons. A considerable amount of research is going on to take solitons out of the lab and into the field.

Fiber Cables

Fiber optic cables are similar to coax, except without the braid. Figure 2-8(a) shows a single fiber viewed from the side. At the center is the glass core through which the light propagates. In multimode fibers, the core is typically 50 microns in diameter, about the thickness of a human hair. In single-mode fibers, the core is 8 to 10 microns. The core is surrounded by a glass cladding with a lower index of refraction than the core, to keep all the light in the core. Next comes a thin plastic jacket to protect the cladding. Fibers are typically grouped in bundles, protected by an outer sheath. Figure 2-8(b) shows

a sheath with three fibers.

Terrestrial fiber sheaths are normally laid in the ground within a meter of the surface, where they are occasionally subject to attacks by backhoes or gophers. Near the shore, transoceanic fiber sheaths are buried in trenches by a kind of seaplow. In deep water, they just lie on the bottom, where they can be snagged by fishing trawlers or attacked by giant squid.

Fibers can be connected in three different ways. First, they can terminate in connectors and be plugged into fiber sockets. Connectors lose about 10 to 20% of the light, but they make it easy to reconfigure systems.

Second, they can be spliced mechanically. Mechanical splices just lay the two carefully cut ends next to each other in a special sleeve and clamp them in place. Alignment can be improved by passing light through the junction and then making small adjustments to maximize the signal. Mechanical splices take trained personnel about 5 minutes and result in a 10% light loss.

Third, two pieces of fiber can be fused (melted) to form a solid connection. A fusion splice is almost as good as a single drawn fiber, but even here, a small amount of attenuation occurs.

For all three kinds of splices, reflections can occur at the point of the splice, and the reflected energy can interfere with the signal.

Two kinds of light sources are typically used to do the signaling. These are LEDs (Light Emitting Diodes) and semiconductor lasers. They have different properties, as shown in Fig. 2-9. They can be tuned in wavelength by inserting Fabry-Perot or Mach-Zehnder interferometers between the source and the fiber. Fabry-Perot interferometers are simple resonant cavities consisting of two parallel mirrors. The light is incident perpendicular to the mirrors. The length of the cav-ity selects out those wavelengths that fit inside an integral number of times.

Mach-Zehnder interferometers separate the light into two beams. The two beams travel slightly different distances. They are recombined at the end and are in phase for only certain wavelengths.

The receiving end of an optical fiber consists of a photodiode, which gives off an electrical pulse when struck by light. The response time of photodiodes, which convert the signal from the optical to the electrical domain, limits data rates to about 100 Gbps. Thermal noise is also an issue, so a pulse of light must carry enough energy to be detected. By making the pulses powerful enough, the error rate can be made arbitrarily small.

Comparison of Fiber Optics and Copper Wire

It is instructive to compare fiber to copper. Fiber has many advantages. To start with, it can handle much higher bandwidths than copper. This alone would require its use in high-end networks. Due to the low attenuation, repeaters are needed only about every 50 km on long lines, versus about every 5 km for copper, resulting in a big cost saving. Fiber also has the advantage of not being affected by power surges, electromagnetic interference, or power failures. Nor is it affected by corrosive chemicals in the air, important for harsh factory environments.

Oddly enough, telephone companies like fiber for a different reason: it is thin and lightweight. Many existing cable ducts are completely full, so there is no room to add new capacity. Removing all the copper and replacing it with fiber empties the ducts, and the copper has excellent resale value to copper refiners who see it as very high-grade ore. Also, fiber is much lighter than copper. One thousand twisted pairs 1 km long weigh 8000 kg. Two fibers have more capacity and weigh only 100 kg, which reduces the need for expensive mechanical support systems that must be maintained. For new routes, fiber wins hands down due to its much lower installation cost. Finally, fibers do not leak light and are

difficult to tap. These properties give fiber good security against potential wiretappers.

On the downside, fiber is a less familiar technology requiring skills not all engineers have, and fibers can be damaged easily by being bent too much. Since optical transmission is inherently unidirectional, two-way communication requires either two fibers or two frequency bands on one fiber. Finally, fiber interfaces cost more than electrical interfaces. Nevertheless, the future of all fixed data communication over more than short distances is clearly with fiber. For a discussion of all aspects of fiber optics and their networks, see Hecht (2005).

2.3 WIRELESS TRANSMISSION

Our age has given rise to information junkies: people who need to be online all the time. For these mobile users, twisted pair, coax, and fiber optics are of no use. They need to get their ‘‘hits’’ of data for their laptop, notebook, shirt pocket, palmtop, or wristwatch computers without being tethered to the terrestrial communication infrastructure. For these users, wireless communication is the answer.

In the following sections, we will look at wireless communication in general. It has many other important applications besides providing connectivity to users who want to surf the Web from the beach. Wireless has advantages for even fixed devices in some circumstances. For example, if running a fiber to a building is difficult due to the terrain (mountains, jungles, swamps, etc.), wireless may be better. It is noteworthy that modern wireless digital communication began in the Hawaiian Islands, where large chunks of Pacific Ocean separated the users from their computer center and the telephone system was inadequate.

2.3.1 The Electromagnetic Spectrum

When electrons move, they create electromagnetic waves that can propagate through space (even in a vacuum). These waves were predicted by the British physicist James Clerk Maxwell in 1865 and first observed by the German physicist Heinrich Hertz in 1887. The number of oscillations per second of a wave is called its frequency, f, and is measured in Hz (in honor of Heinrich Hertz). The distance between two consecutive maxima (or minima) is called the wavelength, which is universally designated by the Greek letter λ (lambda).

When an antenna of the appropriate size is attached to an electrical circuit, the electromagnetic waves can be broadcast efficiently and received by a receiver some distance away. All wireless communication is based on this principle.

In a vacuum, all electromagnetic waves travel at the same speed, no matter what their frequency. This speed, usually called the speed of light, c, is approximately 3 × 108 m/sec, or about 1 foot (30 cm) per nanosecond. (A case could be made for redefining the foot as the distance light travels in a vacuum in 1 nsec rather than basing it on the shoe size of some long-dead king.) In copper or fiber the speed slows to about 2/3 of this value and becomes slightly frequency dependent. The speed of light is the ultimate speed limit. No object or signal can ever move faster than it.

The fundamental relation between f, λ, and c (in a vacuum) is λ f = c (2-4)

Since c is a constant, if we know f, we can find λ, and vice versa. As a rule of

thumb, when λ is in meters and f is in MHz, λ f ~ 300. For example, 100-MHz waves are about 3 meters long, 1000-MHz waves are 0.3 meters long, and 0.1-meter waves have a frequency of 3000 MHz.

The electromagnetic spectrum is shown in Fig. 2-10. The radio, microwave, infrared, and visible light portions of the spectrum can all be used for transmitting information by modulating the amplitude, frequency, or phase of the waves.

Ultraviolet light, X-rays, and gamma rays would be even better, due to their higher frequencies, but they are hard to produce and modulate, do not propagate well through buildings, and are dangerous to living things. The bands listed at the bottom of Fig. 2-10 are the official ITU (International Telecommunication Union) names and are based on the wavelengths, so the LF band goes from 1 km to 10 km (approximately 30 kHz to 300 kHz). The terms LF, MF, and HF refer to Low, Medium, and High Frequency, respectively. Clearly, when the names were assigned nobody expected to go above 10 MHz, so the higher bands were later named the Very, Ultra, Super, Extremely, and Tremendously High Frequency bands. Beyond that there are no names, but Incredibly, Astonishingly, and Prodigiously High Frequency (IHF, AHF, and PHF) would sound nice.

We know from Shannon [Eq. (2-3)] that the amount of information that a signal such as an electromagnetic wave can carry depends on the received power and is proportional to its bandwidth. From Fig. 2-10 it should now be obvious why networking people like fiber optics so much. Many GHz of bandwidth are available to tap for data transmission in the microwave band, and even more in fiber because it is further to the right in our logarithmic scale. As an example, consider the 1.30-micron band of Fig. 2-7, which has a width of 0.17 microns. If we use Eq. (2-4) to find the start and end frequencies from the start and end wavelengths, we find the frequency range to be about 30,000 GHz. With a reasonable signal-to-noise ratio of 10 dB, this is 300 Tbps.

Most transmissions use a relatively narrow frequency band (i.e., Δ f / f << 1). They concentrate their signals in this narrow band to use the spectrum efficiently and obtain reasonable data rates by transmitting with enough power. However, in some cases, a wider band is used, with three variations. In frequency hopping spread spectrum, the transmitter hops from frequency to frequency hundreds of times per second. It is popular for military communication because it makes transmissions hard to detect and next to impossible to jam. It also offers good resistance to multipath fading and narrowband interference because the receiver will not be stuck on an impaired frequency for long enough to shut down communication. This robustness makes it useful for crowded parts of the spectrum, such as the ISM bands we will describe shortly. This technique is used commercially, for example, in Bluetooth and older versions of 802.11.

As a curious footnote, the technique was coinvented by the Austrian-born sex goddess Hedy Lamarr, the first woman to appear nude in a motion picture (the 1933 Czech film Extase). Her first husband was an armaments manufacturer who told her how easy it was to block the radio signals then used to control torpedoes.

When she discovered that he was selling weapons to Hitler, she was horrified, disguised herself as a maid to escape him, and fled to Hollywood to continue her career as a movie actress. In her spare time, she invented frequency hopping to help the Allied war effort. Her scheme used 88 frequencies, the number of keys (and frequencies) on the piano. For their invention, she and her friend, the musical composer George Antheil, received U.S. patent 2,292,387. However, they were unable to convince the U.S. Navy that their invention had any practical use and never received any royalties. Only years after the patent expired did it become popular. (Side note from Jeff: most of the time there is a side note in

these texts, I wrote it. This is not one of those cases!! This can literally be found in the book and I am probably just as suprised as you are!)
A second form of spread spectrum, direct sequence spread spectrum, uses a code sequence to spread the data signal over a wider frequency band. It is widely used commercially as a spectrally efficient way to let multiple signals share the same frequency band. These signals can be given different codes, a method called CDMA (Code Division Multiple Access) that we will return to later in this chapter. This method is shown in contrast with frequency hopping in Fig. 2-11. It forms the basis of 3G mobile phone networks and is also used in GPS (Global Positioning System). Even without different codes, direct sequence spread spectrum, like frequency hopping spread spectrum, can tolerate narrowband interference and multipath fading because only a fraction of the desired signal is lost.
It is used in this role in older 802.11b wireless LANs. For a fascinating and detailed history of spread spectrum communication, see Scholtz (1982).
A third method of communication with a wider band is UWB (Ultra-WideBand) communication. UWB sends a series of rapid pulses, varying their positions to communicate information. The rapid transitions lead to a signal that is spread thinly over a very wide frequency band. UWB is defined as signals that have a bandwidth of at least 500 MHz or at least 20% of the center frequency of their frequency band. UWB is also shown in Fig. 2-11. With this much bandwidth, UWB has the potential to communicate at high rates. Because it is spread across a wide band of frequencies, it can tolerate a substantial amount of relatively strong interference from other narrowband signals. Just as importantly, since UWB has very little energy at any given frequency when used for short-range transmission, it does not cause harmful interference to those other narrowband radio signals. It is said to underlay the other signals. This peaceful coexistence has led to its application in wireless PANs that run at up to 1 Gbps, although commercial success has been mixed. It can also be used for imaging through solid objects (ground, walls, and bodies) or as part of precise location systems.
We will now discuss how the various parts of the electromagnetic spectrum of Fig. 2-11 are used, starting with radio. We will assume that all transmissions use a narrow frequency band unless otherwise stated.

2.3.2 Radio Transmission

Radio frequency (RF) waves are easy to generate, can travel long distances, and can penetrate buildings easily, so they are widely used for communication, both indoors and outdoors. Radio waves also are omnidirectional, meaning that they travel in all directions from the source, so the transmitter and receiver do not have to be carefully aligned physically.
Sometimes omnidirectional radio is good, but sometimes it is bad. In the 1970s, General Motors decided to equip all its new Cadillacs with computer-controlled antilock brakes. When the driver stepped on the brake pedal, the computer pulsed the brakes on and off instead of locking them on hard. One fine day an Ohio Highway Patrolman began using his new mobile radio to call headquarters, and suddenly the Cadillac next to him began behaving like a bucking bronco.
When the officer pulled the car over, the driver claimed that he had done nothing and that the car had gone crazy.
Eventually, a pattern began to emerge: Cadillacs would sometimes go berserk, but only on major highways in Ohio and then only when the Highway Patrol was watching. For a long, long time General Motors could not understand why Cadillacs worked fine in all the other states and also on minor roads in Ohio.

Only after much searching did they discover that the Cadillac's wiring made a fine antenna for the frequency used by the Ohio Highway Patrol's new radio system.

The properties of radio waves are frequency dependent. At low frequencies, radio waves pass through obstacles well, but the power falls off sharply with distance from the source—at least as fast as 1 /r 2 in air—as the signal energy is spread more thinly over a larger surface. This attenuation is called path loss. At high frequencies, radio waves tend to travel in straight lines and bounce off obstacles. Path loss still reduces power, though the received signal can depend strongly on reflections as well. High-frequency radio waves are also absorbed by rain and other obstacles to a larger extent than are low-frequency ones. At all frequencies, radio waves are subject to interference from motors and other electrical equipment.

It is interesting to compare the attenuation of radio waves to that of signals in guided media. With fiber, coax and twisted pair, the signal drops by the same fraction per unit distance, for example 20 dB per 100m for twisted pair. With radio, the signal drops by the same fraction as the distance doubles, for example 6
dB per doubling in free space. This behavior means that radio waves can travel long distances, and interference between users is a problem. For this reason, all governments tightly regulate the use of radio transmitters, with few notable exceptions, which are discussed later in this chapter.

In the VLF, LF, and MF bands, radio waves follow the ground, as illustrated in Fig. 2-12(a). These waves can be detected for perhaps 1000 km at the lower frequencies, less at the higher ones. AM radio broadcasting uses the MF band, which is why the ground waves from Boston AM radio stations cannot be heard easily in New York. Radio waves in these bands pass through buildings easily, which is why portable radios work indoors. The main problem with using these bands for data communication is their low bandwidth [see Eq. (2-4)].

In the HF and VHF bands, the ground waves tend to be absorbed by the earth. However, the waves that reach the ionosphere, a layer of charged particles circling the earth at a height of 100 to 500 km, are refracted by it and sent back to earth, as shown in Fig. 2-12(b). Under certain atmospheric conditions, the signals can bounce several times. Amateur radio operators (hams) use these bands to talk long distance. The military also communicate in the HF and VHF bands.

2.3.3 Microwave Transmission

Above 100 MHz, the waves travel in nearly straight lines and can therefore be narrowly focused. Concentrating all the energy into a small beam by means of a parabolic antenna (like the familiar satellite TV dish) gives a much higher signal-to-noise ratio, but the transmitting and receiving antennas must be accurately aligned with each other. In addition, this directionality allows multiple transmitters lined up in a row to communicate with multiple receivers in a row without interference, provided some minimum spacing rules are observed. Before fiber optics, for decades these microwaves formed the heart of the long-distance telephone transmission system. In fact, MCI, one of AT&T's first competitors after it was deregulated, built its entire system with microwave communications passing between towers tens of kilometers apart. Even the company's name reflected this (MCI stood for Microwave Communications, Inc.). MCI has since gone over to fiber and through a long series of corporate mergers and bankruptcies in the telecommunications shuffle has become part of Verizon. Microwaves travel in a straight line, so if the towers are too far apart, the

earth will get in the way (think about a Seattle-to-Amsterdam link). Thus, repeaters are needed periodically. The higher the towers are, the farther apart they can be. The distance between repeaters goes up very roughly with the square root of the tower height. For 100-meter-high towers, repeaters can be 80 km apart.

Unlike radio waves at lower frequencies, microwaves do not pass through buildings well. In addition, even though the beam may be well focused at the transmitter, there is still some divergence in space. Some waves may be refracted off low-lying atmospheric layers and may take slightly longer to arrive than the direct waves. The delayed waves may arrive out of phase with the direct wave and thus cancel the signal. This effect is called multipath fading and is often a serious problem. It is weather and frequency dependent. Some operators keep 10% of their channels idle as spares to switch on when multipath fading temporarily wipes out some frequency band.

The demand for more and more spectrum drives operators to yet higher frequencies. Bands up to 10 GHz are now in routine use, but at about 4 GHz a new problem sets in: absorption by water. These waves are only a few centimeters long and are absorbed by rain. This effect would be fine if one were planning to build a huge outdoor microwave oven for roasting passing birds, but for communication it is a severe problem. As with multipath fading, the only solution is to shut off links that are being rained on and route around them.

In summary, microwave communication is so widely used for long-distance telephone communication, mobile phones, television distribution, and other purposes that a severe shortage of spectrum has developed. It has several key advantages over fiber. The main one is that no right of way is needed to lay down cables. By buying a small plot of ground every 50 km and putting a microwave tower on it, one can bypass the telephone system entirely. This is how MCI managed to get started as a new long-distance telephone company so quickly. (Sprint, another early competitor to the deregulated AT&T, went a completely different route: it was formed by the Southern Pacific Railroad, which already owned a large amount of right of way and just buried fiber next to the tracks.) Microwave is also relatively inexpensive. Putting up two simple towers (which can be just big poles with four guy wires) and putting antennas on each one may be cheaper than burying 50 km of fiber through a congested urban area or up over a mountain, and it may also be cheaper than leasing the telephone company's fiber, especially if the telephone company has not yet even fully paid for the copper it ripped out when it put in the fiber.

The Politics of the Electromagnetic Spectrum

To prevent total chaos, there are national and international agreements about who gets to use which frequencies. Since everyone wants a higher data rate, everyone wants more spectrum. National governments allocate spectrum for AM and FM radio, television, and mobile phones, as well as for telephone companies, police, maritime, navigation, military, government, and many other competing users. Worldwide, an agency of ITU-R (WRC) tries to coordinate this allocation so devices that work in multiple countries can be manufactured. However, countries are not bound by ITU-R's recommendations, and the FCC (Federal Communication Commission), which does the allocation for the United States, has occasionally rejected ITU-R's recommendations (usually because they required some politically powerful group to give up some piece of the spectrum).

Even when a piece of spectrum has been allocated to some use, such as mobile phones, there is the additional issue of which carrier is allowed to use which frequencies. Three algorithms were widely used in the past. The oldest algorithm, often called the beauty contest, requires each carrier to explain why its proposal serves the public interest best. Government officials then decide

which of the nice stories they enjoy most. Having some government official award property worth billions of dollars to his favorite company often leads to bribery, corruption, nepotism, and worse. Furthermore, even a scrupulously honest government official who thought that a foreign company could do a better job than any of the national companies would have a lot of explaining to do.
This observation led to algorithm 2, holding a lottery among the interested companies. The problem with that idea is that companies with no interest in using the spectrum can enter the lottery. If, say, a fast food restaurant or shoe store chain wins, it can resell the spectrum to a carrier at a huge profit and with no risk.
Bestowing huge windfalls on alert but otherwise random companies has been severely criticized by many, which led to algorithm 3: auction off the bandwidth to the highest bidder. When the British government auctioned off the frequencies needed for third-generation mobile systems in 2000, it expected to get about $4 billion. It actually received about $40 billion because the carriers got into a feeding frenzy, scared to death of missing the mobile boat. This event switched on nearby governments' greedy bits and inspired them to hold their own auctions. It worked, but it also left some of the carriers with so much debt that they are close to bankruptcy. Even in the best cases, it will take many years to recoup the licensing fee.
A completely different approach to allocating frequencies is to not allocate them at all. Instead, let everyone transmit at will, but regulate the power used so that stations have such a short range that they do not interfere with each other.
Accordingly, most governments have set aside some frequency bands, called the ISM (Industrial, Scientific, Medical) bands for unlicensed usage. Garage door openers, cordless phones, radio-controlled toys, wireless mice, and numerous other wireless household devices use the ISM bands. To minimize interference between these uncoordinated devices, the FCC mandates that all devices in the ISM bands limit their transmit power (e.g., to 1 watt) and use other techniques to spread their signals over a range of frequencies. Devices may also need to take care to avoid interference with radar installations.
The location of these bands varies somewhat from country to country. In the United States, for example, the bands that networking devices use in practice without requiring a FCC license are shown in Fig. 2-13. The 900-MHz band was used for early versions of 802.11, but it is crowded. The 2.4-GHz band is available in most countries and widely used for 802.11b/g and Bluetooth, though it is subject to interference from microwave ovens and radar installations. The 5-GHz part of the spectrum includes U-NII (Unlicensed National Information Infrastructure) bands. The 5-GHz bands are relatively undeveloped but, since they have the most bandwidth and are used by 802.11a, they are quickly gaining in popularity.
The unlicensed bands have been a roaring success over the past decade. The ability to use the spectrum freely has unleashed a huge amount of innovation in wireless LANs and PANs, evidenced by the widespread deployment of technologies such as 802.11 and Bluetooth. To continue this innovation, more spectrum is needed. One exciting development in the U.S. is the FCC decision in 2009 to allow unlicensed use of white spaces around 700 MHz. White spaces are frequency bands that have been allocated but are not being used locally. The transition from analog to all-digital television broadcasts in the U.S. in 2010 freed up white spaces around 700 MHz. The only difficulty is that, to use the white spaces, unlicensed devices must be able to detect any nearby licensed transmitters, including wireless microphones, that have first rights to use the frequency band.

Another flurry of activity is happening around the 60-GHz band. The FCC opened 57 GHz to 64 GHz for unlicensed operation in 2001. This range is an enormous portion of spectrum, more than all the other ISM bands combined, so it can support the kind of high-speed networks that would be needed to stream high-definition TV through the air across your living room. At 60 GHz, radio waves are absorbed by oxygen. This means that signals do not propagate far, making them well suited to short-range networks. The high frequencies (60 GHz is in the Extremely High Frequency or ‘‘millimeter’’ band, just below infrared radiation) posed an initial challenge for equipment makers, but products are now on the market.

2.3.4 Infrared Transmission

Unguided infrared waves are widely used for short-range communication. The remote controls used for televisions, VCRs, and stereos all use infrared communication. They are relatively directional, cheap, and easy to build but have a major drawback: they do not pass through solid objects. (Try standing between your remote control and your television and see if it still works.) In general, as we go from long-wave radio toward visible light, the waves behave more and more like light and less and less like radio.

On the other hand, the fact that infrared waves do not pass through solid walls well is also a plus. It means that an infrared system in one room of a building will not interfere with a similar system in adjacent rooms or buildings: you cannot control your neighbor’s television with your remote control. Furthermore, security of infrared systems against eavesdropping is better than that of radio systems precisely for this reason. Therefore, no government license is needed to operate an infrared system, in contrast to radio systems, which must be licensed outside the ISM bands. Infrared communication has a limited use on the desktop, for example, to connect notebook computers and printers with the IrDA (Infrared Data Association) standard, but it is not a major player in the communication game.

2.3.5 Light Transmission

Unguided optical signaling or free-space optics has been in use for centuries. Paul Revere used binary optical signaling from the Old North Church just prior to his famous ride. A more modern application is to connect the LANs in two buildings via lasers mounted on their rooftops. Optical signaling using lasers is inherently unidirectional, so each end needs its own laser and its own photodetec-tor. This scheme offers very high bandwidth at very low cost and is relatively secure because it is difficult to tap a narrow laser beam. It is also relatively easy to install and, unlike microwave transmission, does not require an FCC license.

The laser’s strength, a very narrow beam, is also its weakness here. Aiming a laser beam 1 mm wide at a target the size of a pin head 500 meters away requires the marksmanship of a latter-day Annie Oakley. Usually, lenses are put into the system to defocus the beam slightly. To add to the difficulty, wind and tempera-ture changes can distort the beam and laser beams also cannot penetrate rain or thick fog, although they normally work well on sunny days. However, many of these factors are not an issue when the use is to connect two spacecraft.

One of the authors (AST) once attended a conference at a modern hotel in Europe at which the conference organizers thoughtfully provided a room full of terminals to allow the attendees to read their email during boring presentations.

Since the local PTT was unwilling to install a large number of telephone lines for just 3 days, the organizers put a laser on the roof and aimed it at their

university’s computer science building a few kilometers away. They tested it the night before the conference and it worked perfectly. At 9 A.M. on a bright, sunny day, the link failed completely and stayed down all day. The pattern repeated itself the next two days. It was not until after the conference that the organizers discovered the problem: heat from the sun during the daytime caused convection currents to rise up from the roof of the building, as shown in Fig. 2-14. This turbulent air diverted the beam and made it dance around the detector, much like a shimmering road on a hot day. The lesson here is that to work well in difficult conditions as well as good conditions, unguided optical links need to be engineered with a sufficient margin of error. Unguided optical communication may seem like an exotic networking technology today, but it might soon become much more prevalent. We are surrounded by cameras (that sense light) and displays (that emit light using LEDs and other technology). Data communication can be layered on top of these displays by encoding information in the pattern at which LEDs turn on and off that is below the threshold of human perception. Communicating with visible light in this way is inherently safe and creates a low-speed network in the immediate vicinity of the display. This could enable all sorts of fanciful ubiquitous computing scenarios.

The flashing lights on emergency vehicles might alert nearby traffic lights and vehicles to help clear a path. Informational signs might broadcast maps. Even fes-tive lights might broadcast songs that are synchronized with their display.

2.4 COMMUNICATION SATELLITES

In the 1950s and early 1960s, people tried to set up communication systems by bouncing signals off metallized weather balloons. Unfortunately, the received signals were too weak to be of any practical use. Then the U.S. Navy noticed a kind of permanent weather balloon in the sky—the moon—and built an opera-tional system for ship-to-shore communication by bouncing signals off it.

Further progress in the celestial communication field had to wait until the first communication satellite was launched. The key difference between an artificial satellite and a real one is that the artificial one can amplify the signals before sending them back, turning a strange curiosity into a powerful communication system.

Communication satellites have some interesting properties that make them attractive for many applications. In its simplest form, a communication satellite can be thought of as a big microwave repeater in the sky. It contains several transponders, each of which listens to some portion of the spectrum, amplifies the incoming signal, and then rebroadcasts it at another frequency to avoid interference with the incoming signal. This mode of operation is known as a bent pipe. Digital processing can be added to separately manipulate or redirect data streams in the overall band, or digital information can even be received by the satellite and rebroadcast. Regenerating signals in this way improves performance compared to a bent pipe because the satellite does not amplify noise in the upward signal. The downward beams can be broad, covering a substantial fraction of the earth’s surface, or narrow, covering an area only hundreds of kilometers in diameter.

According to Kepler’s law, the orbital period of a satellite varies as the radius of the orbit to the 3/2 power. The higher the satellite, the longer the period. Near the surface of the earth, the period is about 90 minutes. Consequently, low-orbit satellites pass out of view fairly quickly, so many of them are needed to provide continuous coverage and ground antennas must track

them. At an altitude of about 35,800 km, the period is 24 hours. At an altitude of 384,000 km, the period is about one month, as anyone who has observed the moon regularly can testify.

A satellite's period is important, but it is not the only issue in determining where to place it. Another issue is the presence of the Van Allen belts, layers of highly charged particles trapped by the earth's magnetic field. Any satellite flying within them would be destroyed fairly quickly by the particles. These factors lead to three regions in which satellites can be placed safely. These regions and some of their properties are illustrated in Fig. 2-15. Below we will briefly describe the satellites that inhabit each of these regions.

2.4.1 Geostationary Satellites

In 1945, the science fiction writer Arthur C. Clarke calculated that a satellite at an altitude of 35,800 km in a circular equatorial orbit would appear to remain motionless in the sky, so it would not need to be tracked (Clarke, 1945). He went on to describe a complete communication system that used these (manned) geostationary satellites, including the orbits, solar panels, radio frequencies, and launch procedures. Unfortunately, he concluded that satellites were impractical due to the impossibility of putting power-hungry, fragile vacuum tube amplifiers into orbit, so he never pursued this idea further, although he wrote some science fiction stories about it.

The invention of the transistor changed all that, and the first artificial communication satellite, Telstar, was launched in July 1962. Since then, communication satellites have become a multibillion dollar business and the only aspect of outer space that has become highly profitable. These high-flying satellites are often called GEO (Geostationary Earth Orbit) satellites. With current technology, it is unwise to have geostationary satellites spaced much closer than 2 degrees in the 360-degree equatorial plane, to avoid interference. With a spacing of 2 degrees, there can only be 360/2 = 180 of these satellites in the sky at once. However, each transponder can use multiple frequencies and polarizations to increase the available bandwidth.

To prevent total chaos in the sky, orbit slot allocation is done by ITU. This process is highly political, with countries barely out of the stone age demanding ‘‘their’’ orbit slots (for the purpose of leasing them to the highest bidder). Other countries, however, maintain that national property rights do not extend up to the moon and that no country has a legal right to the orbit slots above its territory. To add to the fight, commercial telecommunication is not the only application. Television broadcasters, governments, and the military also want a piece of the orbiting pie.

Modern satellites can be quite large, weighing over 5000 kg and consuming several kilowatts of electric power produced by the solar panels. The effects of solar, lunar, and planetary gravity tend to move them away from their assigned orbit slots and orientations, an effect countered by on-board rocket motors. This fine-tuning activity is called station keeping. However, when the fuel for the motors has been exhausted (typically after about 10 years) the satellite drifts and tumbles helplessly, so it has to be turned off. Eventually, the orbit decays and the satellite reenters the atmosphere and burns up (or very rarely crashes to earth).

Orbit slots are not the only bone of contention. Frequencies are an issue, too, because the downlink transmissions interfere with existing microwave users. Consequently, ITU has allocated certain frequency bands to satellite users. The main ones are listed in Fig. 2-16. The C band was the first to be designated for commercial satellite traffic. Two frequency ranges are assigned in it, the lower

one for downlink traffic (from the satellite) and the upper one for uplink traffic (to the satellite). To allow traffic to go both ways at the same time, two channels are required. These channels are already overcrowded because they are also used by the common carriers for terrestrial microwave links. The L and S bands were added by international agreement in 2000. However, they are narrow and also crowded.

The next-highest band available to commercial telecommunication carriers is the Ku (K under) band. This band is not (yet) congested, and at its higher frequencies, satellites can be spaced as close as 1 degree. However, another problem exists: rain. Water absorbs these short microwaves well. Fortunately, heavy storms are usually localized, so using several widely separated ground stations instead of just one circumvents the problem, but at the price of extra antennas, extra cables, and extra electronics to enable rapid switching between stations. Bandwidth has also been allocated in the Ka (K above) band for commercial satellite traffic, but the equipment needed to use it is expensive. In addition to these commercial bands, many government and military bands also exist.

A modern satellite has around 40 transponders, most often with a 36-MHz bandwidth. Usually, each transponder operates as a bent pipe, but recent satellites have some on-board processing capacity, allowing more sophisticated operation.

In the earliest satellites, the division of the transponders into channels was static: the bandwidth was simply split up into fixed frequency bands. Nowadays, each transponder beam is divided into time slots, with various users taking turns. We will study these two techniques (frequency division multiplexing and time division multiplexing) in detail later in this chapter.

The first geostationary satellites had a single spatial beam that illuminated about 1/3 of the earth's surface, called its footprint. With the enormous decline in the price, size, and power requirements of microelectronics, a much more sophisticated broadcasting strategy has become possible.

Each satellite is equipped with multiple antennas and multiple transponders. Each downward beam can be focused on a small geographical area, so multiple upward and downward transmissions can take place simultaneously. Typically, these so-called spot beams are elliptically shaped, and can be as small as a few hundred km in diameter. A communication satellite for the United States typically has one wide beam for the contiguous 48 states, plus spot beams for Alaska and Hawaii.

A recent development in the communication satellite world is the development of low-cost microstations, sometimes called VSATs (Very Small Aperture Terminals) (Abramson, 2000). These tiny terminals have 1-meter or smaller antennas (versus 10 m for a standard GEO antenna) and can put out about 1 watt of power. The uplink is generally good for up to 1 Mbps, but the downlink is often up to several megabits/sec. Direct broadcast satellite television uses this technology for one-way transmission.

In many VSAT systems, the microstations do not have enough power to communicate directly with one another (via the satellite, of course). Instead, a special ground station, the hub, with a large, high-gain antenna is needed to relay traffic between VSATs, as shown in Fig. 2-17. In this mode of operation, either the sender or the receiver has a large antenna and a powerful amplifier. The trade-off is a longer delay in return for having cheaper end-user stations.

VSATs have great potential in rural areas. It is not widely appreciated, but over half the world's population lives more than hour's walk from the nearest telephone. Stringing telephone wires to thousands of small villages is far beyond the budgets of most Third World governments, but installing 1-meter VSAT

dishes powered by solar cells is often feasible. VSATs provide the technology that will wire the world.

Communication satellites have several properties that are radically different from terrestrial point-to-point links. To begin with, even though signals to and from a satellite travel at the speed of light (nearly 300,000 km/sec), the long round-trip distance introduces a substantial delay for GEO satellites. Depending on the distance between the user and the ground station and the elevation of the satellite above the horizon, the end-to-end transit time is between 250 and 300 msec. A typical value is 270 msec (540 msec for a VSAT system with a hub).

For comparison purposes, terrestrial microwave links have a propagation delay of roughly 3 μsec / km, and coaxial cable or fiber optic links have a delay of approximately 5 μsec / km. The latter are slower than the former because electromagnetic signals travel faster in air than in solid materials.

Another important property of satellites is that they are inherently broadcast media. It does not cost more to send a message to thousands of stations within a transponder's footprint than it does to send to one. For some applications, this property is very useful. For example, one could imagine a satellite broadcasting popular Web pages to the caches of a large number of computers spread over a wide area. Even when broadcasting can be simulated with point-to-point lines, satellite broadcasting may be much cheaper. On the other hand, from a privacy point of view, satellites are a complete disaster: everybody can hear everything.

Encryption is essential when security is required.

Satellites also have the property that the cost of transmitting a message is independent of the distance traversed. A call across the ocean costs no more to service than a call across the street. Satellites also have excellent error rates and can be deployed almost instantly, a major consideration for disaster response and military communication.

2.4.2 Medium-Earth Orbit Satellites

At much lower altitudes, between the two Van Allen belts, we find the MEO (Medium-Earth Orbit) satellites. As viewed from the earth, these drift slowly in longitude, taking something like 6 hours to circle the earth. Accordingly, they must be tracked as they move through the sky. Because they are lower than the GEOs, they have a smaller footprint on the ground and require less powerful transmitters to reach them. Currently they are used for navigation systems rather than telecommunications, so we will not examine them further here. The constellation of roughly 30 GPS (Global Positioning System) satellites orbiting at about 20,200 km are examples of MEO satellites.

2.4.3 Low-Earth Orbit Satellites

Moving down in altitude, we come to the LEO (Low-Earth Orbit) satellites.

Due to their rapid motion, large numbers of them are needed for a complete system. On the other hand, because the satellites are so close to the earth, the ground stations do not need much power, and the round-trip delay is only a few milliseconds. The launch cost is substantially cheaper too. In this section we will examine two examples of satellite constellations for voice service, Iridium and Globalstar.

For the first 30 years of the satellite era, low-orbit satellites were rarely used because they zip into and out of view so quickly. In 1990, Motorola broke new ground by filing an application with the FCC asking for permission to launch 77 low-orbit satellites for the Iridium project (element 77 is iridium). The

plan was later revised to use only 66 satellites, so the project should have been renamed Dysprosium (element 66), but that probably sounded too much like a disease. The idea was that as soon as one satellite went out of view, another would replace it.

This proposal set off a feeding frenzy among other communication companies. All of a sudden, everyone wanted to launch a chain of low-orbit satellites. After seven years of cobbling together partners and financing, communication service began in November 1998. Unfortunately, the commercial demand for large, heavy satellite telephones was negligible because the mobile phone network had grown in a spectacular way since 1990. As a consequence, Iridium was not profitable and was forced into bankruptcy in August 1999 in one of the most spectacular corporate fiascos in history. The satellites and other assets (worth $5 billion) were later purchased by an investor for $25 million at a kind of extraterres-trial garage sale. Other satellite business ventures promptly followed suit.

The Iridium service restarted in March 2001 and has been growing ever since. It provides voice, data, paging, fax, and navigation service everywhere on land, air, and sea, via hand-held devices that communicate directly with the Iridium satellites. Customers include the maritime, aviation, and oil exploration industries, as well as people traveling in parts of the world lacking a telecom infrastructure (e.g., deserts, mountains, the South Pole, and some Third World countries).

The Iridium satellites are positioned at an altitude of 750 km, in circular polar orbits. They are arranged in north-south necklaces, with one satellite every 32
degrees of latitude, as shown in Fig. 2-18. Each satellite has a maximum of 48 cells (spot beams) and a capacity of 3840 channels, some of which are used for paging and navigation, while others are used for data and voice.

With six satellite necklaces the entire earth is covered, as suggested by Fig. 2-18. An interesting property of Iridium is that communication between distant customers takes place in space, as shown in Fig. 2-19(a). Here we see a caller at the North Pole contacting a satellite directly overhead. Each satellite has four neighbors with which it can communicate, two in the same necklace (shown) and two in adjacent necklaces (not shown). The satellites relay the call across this grid until it is finally sent down to the callee at the South Pole.

An alternative design to Iridium is Globalstar. It is based on 48 LEO satellites but uses a different switching scheme than that of Iridium. Whereas Iridium relays calls from satellite to satellite, which requires sophisticated switching equipment in the satellites, Globalstar uses a traditional bent-pipe design. The call originating at the North Pole in Fig. 2-19(b) is sent back to earth and picked
up by the large ground station at Santa’s Workshop. The call is then routed via a terrestrial network to the ground station nearest the callee and delivered by a bent-pipe connection as shown. The advantage of this scheme is that it puts much of the complexity on the ground, where it is easier to manage. Also, the use of large ground station antennas that can put out a powerful signal and receive a weak one means that lower-powered telephones can be used. After all, the telephone puts out only a few milliwatts of power, so the signal that gets back to the ground station is fairly weak, even after having been amplified by the satellite.

Satellites continue to be launched at a rate of around 20 per year, including ever-larger satellites that now weigh over 5000 kilograms. But there are also very small satellites for the more budget-conscious organization. To make space research more accessible, academics from Cal Poly and Stanford got together in

1999 to define a standard for miniature satellites and an associated launcher that would greatly lower launch costs (Nugent et al., 2008). CubeSats are satellites in units of 10 cm × 10 cm × 10 cm cubes, each weighing no more than 1 kilogram, that can be launched for as little as $40,000 each. The launcher flies as a secondary payload on commercial space missions. It is basically a tube that takes up to three units of cubesats and uses springs to release them into orbit. Roughly 20
cubesats have launched so far, with many more in the works. Most of them communicate with ground stations on the UHF and VHF bands.

Estimated time: 41 minutes.
Source: Computer Networks, 5th edition by Tanenbaum

C.4 Main Experiment Questionnaires

C.4.1 Disney

Questionnaire text Walt Disney

Correct answers are marked with a *

1. Please fill in your name

2. Before or after reading the text

    - before
    - after

3. How many brothers and sisters did Walt Disney have?

    - 2
    - 3
    - 4 *
    - 5
    - I don't know

4. What did Disney have to draw for his first Drawing job?

    - Horse *
    - Rabbit
    - Mouse
    - Dog
    - I don't know

5. Who introduced Disney to the world of motion picture?

    - A friend from school *
    - One of his brothers
    - His neighbour
    - His father
    - I don't know

6. Why was Disney rejected to fight in WW1?

    - His eye sight was too poor
    - He was too young *
    - He wasn't fast enough
    - His couldn't properly walk because of an acident he had at a young age
    - I don't know

7. What was the name of the first series of cartoons Disney produced?

    - Mickey shorts
    - The Mickey Mouse Club
    - Adventures in Wonderland
    - Laugh-O-Grams *

- I don't know

8. What was the name of the first animated pet Disney created?

    - Donald Duck
    - Mickey Mouse
    - Pluto
    - Oswald the Rabbit *
    - I don't know

9. What was the original name of Mickey Mouse?

    - Oswin Mouse
    - Mortimer Mouse *
    - Mike Mouse
    - Marvin Mouse
    - I don't know

10. What cartoon was the first Disney cartoon to feature synchronized sound?

    - Steamboat Willie *
    - Building a building
    - Mickey Mouse, the band concert
    - Pluto lend a paw
    - I don't know

11. What was the first feature length cartoon Disney created?

    - Pinocchio
    - Fantasia
    - Snow White *
    - Alice in Wonderland
    - I don't know

12. How did Disney created a sense of depth in its cartoons?

    - By having a seperate animator draw depth lines, estimating the depth and movement respectively
    - By adding multiple layers of drawings to the camera that could move independently, background layers and foreground were seperate, partially transparent, drawings *
    - While drawing the images, consistently moving the background respectively of the character (single drawing)
    - By drawing one wide background, then copying frames of that background and draw the foreground on it
    - I don't know

13. Which cartoon's production was shortly halted due to a strike of the staff?

    - The Reluctant Dragon
    - Bambi
    - Dumbo *

- The Three Caballeros
- I don't know

14. During WW2, Disney created propaganda for the US. Which Disney character was prominently featured in these cartoons?

    - Donald Duck *
    - Pluto
    - Goofy
    - Mickey Mouse
    - I don't know

15. What link did Disney have with the FBI?

    - He secretly passed information to the FBI *
    - He had a brother who worked for the FBI
    - From a young age he wanted to join the FBI
    - He wanted to make a cartoon with Donald Duck as FBI agent
    - I don't know

16. In 1951 Disney created a movie he wanted to produce from the beginning of his movie-making career. What movie was this?

    - Peter Pan
    - Cinderella
    - Lady and the Tramp
    - Alice in Wonderland *
    - I don't know

17. When did Disney come up with the idea for Disneyland (as the story goes, while ...) ?

    - During production of Fantasia
    - While visiting Tivoli Gardens in Denmark
    - While sitting on a bench, watching his kids ride the Marry-go-round *
    - While riding his train on his private track in his garden, together with his children
    - I don't know

18. Did Disney ever visit the Efteling and what is the story behind it?

    - Yes he did, though the visit was in secret so no pictures exist
    - Yes he did, but the picture have been lost in time
    - No he did not, the Efteling did not exist in the time he would have gone according to the story
    - No he did not, it was a misunderstanding of the press *
    - I don't know

19. What does WED enterprises stand for and what was the main goal of this company?

    - Walt's Europe Disney, it's the european branch of the company
    - Walt E. Disney, the company was responsible of creating rides and experiences for the Disney parks and Worlds Fair *
    - Walt Elective Democrat, the company ran Walt Disney's run for presidency

- Walt's Envisioning Departement, the company came up with new ideas for cartoons and other movies
- I don't know

20. What TV broadcasting company did Disney work with to fund Disneyland?

- CNBC
- CNN
- ABC *
- FOX
- I don't know

21. What sports-event was Disney involved in?

- Superbowl
- FIFA world cup
- Formula 1 Caesars Palace Grand Prix in Las Vegas
- Olympic games *
- I don't know

22. How many rides did Disney create for the New York World's Fair?

- 1
- 2
- 3
- 4 *
- I don't know

23. Why did the original Peoplemover/Rocket Rotts have to close?

- Low attendance
- Problems with the construction *
- Safety issues with the restraints
- High maintencance costs
- I don't know

24. What does the acronym EPCOT stand for?

- Experimental Prototype Community Of Tomorrow *
- Exhibition Prototype Center Of Technology
- Every Person Comes Out Tired
- Expansion Paris China Orlando Torronto
- I don't know

25. What probably caused the death of Disney?

- Drugs abuse
- Heavy smoking *
- Unhealthy diet
- Depression
- I don't know

26. What remnant of the original idea of EPCOT can still be found and where?

- A maquette of the original plans, in the peoplemover in Orlando *
- Blueprints in a museum in the original Disneyland park in California
- A maquette of the original plans, in the center of the EPCOT amusement park in Orlando
- Blueprints at the entrance of the EPCOT amusement park in Orlando
- I don't know

27. Disney often operated a specific ride in Disneyland? Which ride?

- The Snow White ride
- The Peter Pan ride
- The peoplemover
- The steamtrain *
- I don't know

28. What happened to the roads on opening day?

- The roads were overly crowded
- The roads started melting *
- People did not see the difference between staff-only roads and guest-accessible roads
- The roads were too rough for strollers
- I don't know

29. What was the main complaints about the rides in Disneyland?

- The rides were to short
- The main characters of the ride where nowhere to be found *
- The lines were too long
- The rides were boring for adults
- I don't know

30. What was an additional complaint about the Snow White ride?

- It was too scary for children *
- The ride was too warm inside
- Children did not understand the ending of the ride
- There was a double meaning somewhere in the ride which parents did not approve of
- I don't know

31. Why was club 33 created?

- To have a place that served alcohol in the park, off limits of the regular guests *
- For the employees to have a drink together after work
- For VIPS to have a place to get away from fans
- To decorate an empty building, many fans believed it to be a secret club, but it never actually existed
- I don't know

32. What memorial of Walt Disney can be found in Disneyland?

- A light that symbolizes Walt's spirit and presence at Disneyland *
- A statue of Walt, overlooking the entrance of Disneyland
- His most beloved bowtie, hanging in a display at the trainstation at main street
- A small picture of Walt, hanging in every locomotive of the railroad.
- I don't know

33. Which country where the last to be considered for Disneyland in Europe, besides France?

- Spain *
- Germany
- UK
- Italy
- I don't know

34. Why was Paris chosen for Disneyland?

- It's rich culture
- The cheap land
- It's central location in Europe *
- The big plot of land with lots of expansion opertunities
- I don't know

35. What theme was exclusively used for the hotels in Disneyland Paris?

- American *
- Classical
- European
- Modern
- I don't know

36. Where were the recipes for DP (Disneyland Paris) originally tested?

- Test kitchens in Tokyo Disney
- Test kitchens in Disneyland California
- Test kitchens in Walt Disney World, Orlando *
- Test kitchens at the WDI workshop
- I don't know

37. In which three European countries where employees sought?

- France, UK, Netherlands *
- France, UK, Germany
- France, Netherlands, Spain
- France, Belgium, Spain
- I don't know

38. What concern did the french have on DP?

- Cultural Imperialism *
- Too much road traffic
- Too many tourists in the residential towns around DP

- Unfair competition with other French amusementparks
- I don't know

39. What can be said about the crowd-level on the openingday of DP?

- Higer then expected
- As expected
- Lower then expected *
- I don't know

40. What was one of the complaints about the food in DP?

- Too many American fast food options
- No wine was served at diner *
- The average amount of salt used in European food is lower then American, the guests found the food too salty
- No drink options apart from soda were available
- I don't know

41. What incorrect assumptions did Disney make about European people when they made DP?

- The capability to speak English, especially for the French people, was lower then expected
- The travel distance people find long distance was lower then expected *
- Europeans will come from countries surrounding France will come one day instead of staying at one of the hotels
- The willingness to buy balloons was lower then expected
- I don't know

42. What is the "tomorrowland issue" and how is this solved in DP?

- Lack of capacity, made Space Mountain with longer trains and two different stations to increase capacity
- Lack of consistent theming, most of Discoveryland is themed after the Jules Vergne stories, other stories are put in the back
- Lack of kid oriented rides, included the astro-orbitors and moved autopia to Discoveryland
- "Tommorow" aging too fast, making Discoveryland, a steam-punk/alternate version of the future *
- I don't know

43. What ride mostly saved DP from closure?

- Buzz Lightyear - laser blast
- Big Thunder Mountain
- Space Mountain *
- Indiana Jones rollercoaster
- I don't know

44. Why was the Walt Disney Studios Park build?

- They where obligated because of a contract with the French government *
- To increase capacity and reduce waiting times in the main park

- To create extra revenue while DP was not making a big profit
- To make sure Disney would not lose the land to the French government
- I don't know

45. Why did both parks on the paris resort close for the first time?

- Because of COVID
- Because of the attack at Charlie Hebdo
- November 2015 paris attacks (Bataclan) *
- Because of an unfortunate accident on the Railroad
- I don't know

46. Which 3 new IP's (Intellectual Properties) where announced for the Walt Disney Studios Park in 2018?

- Frozen, Coco, Avatar
- Mickey Mouse, Coco, Star Wars
- Marvel, Avatar, Mickey Mouse
- Frozen, Star Wars, Marvel *
- I don't know

47. What are Jeffrey's expectations about the fate of the studio tram tour ride?

- It is a cheap overhall to keep capacity, will be closed when capacity of the park is up *
- It is a fully detailed overhall, here to stay as a stand alone ride
- The overhall will be the start of a new cars land with more rides
- It is made in a way so it can later be expanded when the 3 new lands are done
- I don't know

48. How many times did DP close due to COVID?

- 1
- 2 *
- 3
- 4
- I don't know

49. Is DP currently opened?

- Yes
- No *
- Partially, just outside attractions are opened
- Partially, just restaurants are opened
- I don't know

C.4.2 ISS

Questionnaire text ISS

Correct answers are marked with a *

1. Please fill in your name
2. Before or after reading the text
    - before
    - after
3. The ISS is mainly operated by two different countries. Which countries?
    - Russia and USA *
    - Canada and USA
    - Russia and Canada
    - China and USA
    - I don't know
4. Which space station is the previous record holder for the longest continuous human presence in low Earth orbit?
    - Mir *
    - Tiangong 1
    - Tiangong 2
    - Skylab
    - I don't know
5. What takes up a considerable amount of crew time aboard the station?
    - Exercise
    - Station maintenance *
    - Media events
    - Satellite spotting
    - I don't know
6. What finding supported the notion of panspermia, the hypothesis that life exists throughout the Universe, distributed in various ways.
    - Space dust was found to contain bacteria
    - Bacteria can survive up to 3 years in space *
    - Micro-organisms that can survive in space, without oxygen, where found
    - While cleaning the ISS, astronauts found bacteria that where 20 years old, that where brought from earth when the specific module of the ISS was launched.
    - I don't know
7. How strong is gravity at the altitude of the ISS?
    - 0% as strong as at Earth's surface

- 30% as strong as at Earth's surface
- 60% as strong as at Earth's surface
- 90% as strong as at Earth's surface *
- I don't know

8. What role does the ISS play in the new long-duration moon and mars missions of NASA?

- Serve as a hub to reduce the energy used during launch
- Provide a location to test spacecraft systems with relative safety *
- Proide an emergency storage facility
- Provide the posibility to work on spacecrafts
- I don't know

9. What is one area that benefits of fluids physics aboard the ISS?

- Microbiology
- Thermodynamics
- Blood pressure analysis
- Superconductivity *
- I don't know

10. What does ARISS stand for?

- Augmented Reality on the ISS
- Amateur Radio on the ISS *
- Automatic Repositioning Ionthruster Safety System
- Automatic Repositioning of the ISS
- I don't know

11. What special thing did Chris Hadfield do aboard the ISS?

- He shot a videoclip *
- He wrote the first python code in space
- He shot a short movie of his daughters teddy bear having adventures in space
- He was the first man to pee while on a spacewalk
- I don't know

12. Who created the arm that is used to berth (dock) spacecrafts?

- NASA (USA)
- ESA (Europe)
- CSA (Canada) *
- Roscosmos (Rusia)
- I don't know

13. Which country delivered the first resident crew to the ISS using the Soyuz rocket (Expedition 1)

- Rusia *
- USA
- Canada
- China

- I don't know

14. What air pressure is used aboard the ISS?

    - Pressure slightly above regular
    - Pressure equal to 10 meters above sea level
    - Pressure at Earths sea level *
    - Pressure slightly below sea level
    - I don't know

15. What power does the USOS use? (outlet voltage)

    - 5 V DC
    - 28 V DC
    - 124 V DC *
    - 240 V DC
    - I don't know

16. The ISS used to run on NiH2 batteries. What batteries are currently used?

    - Superconductors
    - Li-Ion *
    - Lead-acid
    - LFP (Lithium iron phosphate)
    - I don't know

17. What frequency range does the Voskhod-M communications system use to communicate with ground control?

    - HF
    - VHF *
    - UHF
    - SHF
    - I don't know

18. What operating systems do the computer systems, responsible for the stations key features, currently run?

    - Microsoft Windows
    - MacOs
    - Debian Linux *
    - Arch Linux
    - I don't know

19. What caused the crew size to be reduced on expedition 7 to 12?

    - Explosion of the Shuttle Columbia *
    - Cost cutting measures, financial crisis
    - Experiments to loneliness aboard the ISS
    - Problems with one of the water systems resulting in less water aboard the station
    - I don't know

20. In 2008, spaceflight participant Richard Garriott was the first to participate in a certain game aboard the ISS. What was this game?

    - Chess
    - Jenga
    - Poker
    - Geocaching *
    - I don't know

21. In what spacecrafts did the 7 spaceflight participants ("space tourists") ride to go to the ISS?

    - Soyuz (Russian) *
    - Apollo (NASA)
    - Space shuttle (NASA)
    - Crew Dragon (SpaceX)
    - I don't know

22. Which of the following spacecrafts has the most sophisticated, but reliable docking procedure?

    - Soyuz (Russian) *
    - Apollo (NASA)
    - Space Shuttle (NASA)
    - Crew Dragon (SpaceX)

23. What are ORUs?

    - Orbital Rendezvous Unidirector - The system used to rendezvous spacecrafts
    - Oatmeal Ration Units - Rations that can be used in case of an emergency
    - Orbital Replacement Units - spare parts that can be readily replaced *
    - Overall Refridgeration Unit - Refridgeration system in place to store fresh foods
    - I don't know

24. Which company largely built the USOS's cooling system?

    - Boeing *
    - SpaceX
    - IBM
    - Whirlpool
    - I don't know

25. What do the Main Bus Switching Units do?

    - Connect multiple computers directly to control the ISS's systems redundantly. Direct connection between the CPU busses.
    - Switch power between the redundant power systems
    - Control the routing of power from the solar arrays to the rest of the ISS *
    - Cuts power from a seperate module in case of a fire
    - I don't know

26. What timezone is used on the ISS?

- CT
- CET
- Moscow Time
- UTC *
- I don't know

27. Why are cans of food rarely used aboard the ISS?

    - Because of the sharp edges that may cause harm to the ISS
    - Because of metal shavings that can come of when opening a can. These shavings can harm the air systems
    - Because they are heavy and expensive, compared to plastic bags *
    - Because they will pop under the pressure during launch
    - I don't know

28. In 2019, NASA reported results of the Astronaut Twin Study. Scott Kelly spent a year on the ISS while his twin spent this year on Earth. What was found to have changed in space during this study?

    - Amount of bloodcells
    - DNA *
    - Density of bones
    - Hair thickness
    - I don't know

29. How much radiation are astronauts exposed to per day?

    - Half a year's worth of natural exposure on Earth
    - One year's worth of natural exposure on Earth *
    - One and a half year's worth of natural exposure on Earth
    - Two year's worth of natural exposure on Earth
    - I don't know

30. What is a main source of stress aboard the ISS (currently)?

    - Maintaining high performance
    - Isolation from family and peers *
    - Lack of fresh food
    - The sense of being locked up
    - I don't know

31. What can be a main problem of bacteria that can develop aboard the ISS? (currently known)

    - Degradation of metal, glass and rubber *
    - Hygene/health of the crew
    - Cause problems for experiments within a controlled air / bacteria free environment
    - Water polution
    - I don't know

32. What causes reduced alarm audibility aboard the ISS?

    - Constant noise *

- Too many alarms
- Alarms with frequency close to auditory noise
- Too many different sounds that all sound the same
- I don't know

33. What was one of the reasons the ISS's orbit was chosen?

- Because of the speed the ISS falls at on this altitude, it makes communication easier
- To make sure the ISS is visible from Earth with the naked eye
- Because of the temperature at this level
- It the lowest inclination the Soyuz can directly reach safely *
- I don't know

34. Until what size can the optical and radar instruments detect space debris?

- 1 cm *
- 1 dm
- 1 m
- 1 km
- I don't know

35. Until what year will the ISS at least be operational?

- 2022
- 2030 *
- 2042
- 2085
- I don't know

36. What did the ISS totally cost until 2010?

- US$175 thousand
- US$100 million
- US$150 billion *
- US$125 trillion
- I don't know

C.4.3 Physical layer of Computer Networks

Questionnaire text Physical layer computer networks

Correct answers are marked with a *

1. Please fill in your name

2. Before or after reading the text

    - before
    - after

3. Media are grouped into guided and unguided media. What can be seen as guided media?

    - Copper wires and fiber optics *
    - Satelites and lasers through air
    - TCP packets
    - UDP packets
    - I don't know

4. What is the most cost-effective way of data transfer?

    - Network transfer
    - Satellite transmission
    - Tape *
    - USB
    - I don't know

5. Why are the cables of twisted pairs twisted?

    - The twisting cancels out the EM waves produced by the wires *
    - The twisting keeps the cables together
    - People thought that twisting the cables would make the cable faster. This is - proven wrong, but they still keep it as an old convention
    - The twisting makes the cable stronger
    - I don't know

6. What standard did Cat 5 replace?

    - Cat 1
    - Cat 3 *
    - Cat 4
    - Cat 4e
    - I don't know

7. What is the difference between coax and unshielded twisted pairs?

    - Coax is faster and spans a longer distance *
    - Coas is faster, but spans a shorter distance
    - Coax is slower, but spans a longer distance

- Coax is slower and spans a shorter distance
- I don't know

8. What can be a problem with using household electrical wiring for a network?

   - The fact that the network has to work on high voltage, rather then low voltage
   - The low frequency of 50-60 Hz power runs at, at homes *
   - The wires in homes are too thick to easily transfer data
   - A typical households electrical wiring caps out at 1 Mbps
   - I don't know

9. Why is the current limit of network transfer 100 Gbps?

   - Physical limit of fiber optic wires
   - Physical limit of coper wires
   - Inability to transfer between fiber and coper signals *
   - Overhead in the current network protocols
   - I don't know

10. How far can current fiber optic cables transfer data at a speed of 100 Gbps without amplification?

    - 5 cm
    - 30 m
    - 100 km *
    - 20000 km
    - I don't know

11. What danger can the transoceanic fiber sheaths in deep water be exposed to?

    - Boats hitting them with the propeller
    - Boats moving them with the waves created by the propeller
    - Fish creating nests underneath them, pushing around the sensitive cable
    - Giant squid attacks *
    - I don't know

12. What light sources are typically used on fiber optic cables?

    - LEDs and semiconductor lasers *
    - LEDs and UV lasers
    - Semiconductor lasers and UV lasers
    - X-ray and Gamma ray producers
    - I don't know

13. What would be the benefit of using UV, X-rays and Gamma rays for wireless transfer?

    - Lower transfer delay
    - Higher transfer speed *
    - Better transmition through walls
    - Saver for human beings
    - I don't know

14. Who coinvented the technique of frequency hopping spread spectrum used on Bluetooth and older versions of 802.11?

    - The U.S. navy during WW2
    - The German army during WW2
    - Researchers of IBM
    - The first woman to ever appear nude in a motion picture *
    - I don't know

15. What is the advantage of UWB (ultra-wide band)?

    - High transmission distance
    - Better transmission through wall
    - High communication rate *
    - Low loss rate
    - I don't know

16. In the 1970s, Cadillac installed a certain system in there cars. These systems were interfered by the radios of the police. Which system was this?

    - Music radios, when the police would talk on their radio system, people would hear the transmission through there music radio.
    - Antilock brakes, when the police would transmit on there radios, the brakes would start jittering *
    - Electronic fuel pumps, when the police would start talking the motor would start jittering
    - Remote rear windscreen wipers, when the police would start transmitting, the wiper would turn on and off
    - I don't know

17. What is disadvantage of HF and VHF?

    - Ground waves tend to be absorbed by the Earth *
    - Ground waves tend to be absorbed by walls
    - Waves easily cancel out
    - Waves are maybe unsafe to humans
    - I don't know

18. What does MCI stand for?

    - Mobile Contractor Inc
    - Microwave Communications Inc *
    - Multi Channel Intermission
    - Many Channel Intermission
    - I don't know

19. What problem occurs at the 4 GHz band?

    - Absorption by buildings
    - Shorter distance without amplification
    - Absortion by water, including rain *
    - Straight transmission, rather then curved. (Seattle-Amsterdam would not be possible)

- I don't know

20. What does ISM bands stand for?

- Industry, Scientific, Medical *
- Industry, Sport, Marine
- Intercommunication Space and Marine
- Industry, Scientific, Marine
- I don't know

21. What are infrared waves widely used for?

- Submarine communication
- Long-range communication
- Short-range communication *
- Space communication (ISS)
- I don't know

22. In its simplest form, what can a communication satellite be thought of?

- A big microwave repeater *
- A big network router
- A big cellphone tower
- A big piece of scrap metal
- I don't know

23. Why did Clarke conclude that satellites where impractical?

- The lack of power produced by solar arrays at the time
- Impossibility of keeping the satelite visible to the user for long enough to - transmit data
- Impossibility of keeping the satelite in orbit
- Impossibility of putting power-hungry, fragile vacuum tube amplifiers into orbit *
- I don't know

24. What is station keeping?

- Keeping a satellite in orbit *
- Maintenance done to a satellite
- Sign-of-life signals from satellites to the ISS
- A robot vaccuum called wheetly floating through space cleaning solar arrays of satellites
- I don't know

25. What is a problem with the Ku band used by satellites?

- The waves are straight, so they need to be pointed very precisely
- The transfer rate is not high
- It interfereces with microwaves used on Earth
- Rain absorbs the waves *
- I don't know

26. What does MEO stand for?

- Middle-Earth orbit
- Magnetic-Electric-oscilation
- Medium-Earth orbit *
- Minimal Emition Orientation
- I don't know

27. Which company was responsible for the Iridium project with 77 low orbit satellites?

- NASA
- Boeing
- Motorola *
- IBM
- I don't know

28. How many satellites are launched per year? (Keep in mind this is before starlink of SpaceX)

- 1
- 20 *
- 100
- 1000
- I don't know