Since its introduction in the Royal Netherlands Air Force (RNLAF) fleet in 1979, the F-16 “Fighting Falcon” has been continuously upgraded to remain a state-of-the-art multi-role fighter/bomber. These upgrades include new weapons, avionics and mission software, the largest modification being the Mid-Life-Update (MLU). Flight testing was, and still is, necessary to support development and testing of F-16 upgrades. The Netherlands Ministry of Defence (MoD) operates its equipment using a Smart Buyer – Smart Operator concept. From this concept a requirement for an F-16 flight test capability was formulated, after which the Netherlands F-16 Flight Test Office (F-16 FTO) was founded in 1984. Since 1984 the F-16 FTO has operated a number of F-16 flight test aircraft, all in various configurations. Currently the F-16 FTO operates a specially modified, F-16BM flight test aircraft, affectionately called the “Orange Jumper”.

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ORGANIZATION
Being able to perform F-16 flight tests and participating in the Multi National Fighter Program (MNFP) with other F-16 operating nations (Belgium, Denmark, Norway and Portugal) enables the RNLAF to meet the operational requirements for the F-16 more efficiently and effectively.

The F-16 is not the only aircraft in the Netherlands military fleet with upgrade requirements and thus requiring flight testing. The Operational Research and Evaluation (AORE) department embodies the overall organization coordinating all flight test activities with Dutch military aircraft, e.g. F-16; AH-64 Apache, C-130 etc. The AORE department coordinates with the Air Staff, Military Airworthiness Authority (MLA) and the Defence Material Organization (DMO) if new or modified operational needs for an aircraft require flight testing and, if required, issues flight test orders to the flight test office related to that particular type of aircraft.

The DMO, Fighter and Training Aircraft Division, acts as the Military Type Certificate (MTC) holder for the Netherlands F-16 fleet. Most new modifications, upgrades and configuration changes require a flight test as part of the requirement compliance demonstration in the certification process. DMO works closely together with AORE and the various flight test offices preparing these tests. During test pro-
gram preparations a Test Objective (TO), (preliminary) engineering & documentation, No Technical Objection (NTO), Risk Analyses (RA) and a Test Plan (TP) are re-
required. In most cases a ‘Permit to Fly’ is re-
quired from the MLA in order to ‘legally’ fly in an uncertified aircraft configuration.
This overall test organization structure
ensures a do-check-approve cycle is guar-
anteed and flight testing with maximum safety and minimum risk is safeguarded.

The F-16 FTO is based at Leeuwarden
Air Base and is part of the 323 Tactical,
Training, Evaluation and Standardization
Squadron (TACTESS), which is a perfect fit
for the F-16 FTO. One of the 323 TACTES
Squadron tasks is to evaluate new F-16
upgrades and determine how to use them
effectively in an operational sce-
nario followed by standardization of this
upgrade in new operating procedures.
Currently test orders are executed at
the F-16 FTO by a test pilot, a flight test
engineer and two avionics/instrumentation
technicians. In close cooperation with
323 squadron and other air base users the
F-16 FTO operates the F-16BM with tail
number J-066.

**J-066 “ORANGE JUMPER” F-16BM FLIGHT TEST AIRCRAFT**
In the past F-16 flight test aircraft mostly
carried their instrumentation in an exter-
nal pod or as a replacement for mission
related hardware (usually the ammodrum
and M61A gun) inside the aircraft, thus
resulting in a flight test aircraft no longer
able to fly operational training missions.
Reductions in the number of operational
F-16 aircraft led to the requirement that a
new RNLAF F-16 flight test aircraft should
be able to meet all current and future
flight test demands and still remain fully
mission capable, meaning no hardware
could be removed.

When the J-066 was designated as flight
test aircraft the flight test department of
the National Aerospace Laboratory NLR
was commissioned by the DMO to de-
sign, in cooperation with DMO engineers,
a fully modular F-16 instrumentation sys-
tem without affecting the aircraft mission
capability. The entire modification took
nine months and the design proved to be
a success. Up until today the J-066 “Or-
ge Jumper” remains a fully operational
aircraft, currently at the highest modifi-
cation standard of the RNLAF F-16 fleet
and capable of fulfilling all flight test de-
mands.

**J-066 AIRCRAFT INSTRUMENTATION**
F-16 avionics communicate with each
other using a MIL-STD-1553 data bus ar-
boutecture. One of the requirements of
the instrumentation system was to be
able to record all MIL-STD-1553 data. This
would enable engineers to analyse
aircraft behaviour during and after a
flight test. A Programmable Conditioner
Unit (PCU) captures all MIL-STD-1553 data
and sends it to a Programmable Master
Unit (PMU), which is the core element
of the instrumentation system. The PMU
not only collects PCU data but also data
from several aircraft independent sen-
sors distributed along the airframe. Being
able to measure aircraft behaviour us-
ing independent sensors is vital to flight
testing. When avionics or other hardware
has been replaced with new or other ver-
sions they have to be validated. This can
only be done using aircraft independent
flight test systems. In order to incorporate
a modular sensor design, generic sensor
interfaces (Micro Miniature Signal Conditioner, MMSC) are placed
designed and connected to
all the various channels,

The PMU combines all data and distrib-
utes it to four Solid State Recorders (SSR) and an Aft Seat Hud Monitor (ASHM) all located in the after cockpit using the air-
craft independent instrumentation data
bus. The ASHM is a unique feature. It in-
corporates a PC and enables the flight test
engineer in the aft cockpit to monitor and
manage the flight test progress in real-
time.

All instrumentation is fully configurable
and can be reconfigured within a few
hours using a dedicated programming
tool. Combined with the generic sensor
interfaces all kinds of measurement sen-
sors (accelerometers, strain gauges etc.)
can be integrated in the instrumentation system without the need for large scale aircraft modifications. The J-066 has an elongated pitot tube (affectionately called the ‘Viagra boom’) with high precision angle of attack and sideslip vanes capable of measuring both angles up to 0.2° accurate. On top of all that, the J-066 is capable of carrying newly modified missile launchers (figure 2) and wing weapon pylons, which, equipped with sensors, can be connected to the instrumentation data bus as well. Link16 tactical data link traffic can be recorded using a Multifunctional Information Distribution System (MIDS) recorder. Finally, the system also has the capability of recording images from five high speed cameras which can be controlled simultaneously and can be used to film wing store separations (figure 3).

The instrumentation bus installation and implementation of MIL-STD-1533 recording capabilities required additional wiring to be inserted in the F-16 data bus architecture. This technique is called ‘jumpering.’ Combined with the fact that flight test cables and equipment is orange by default earned the J-066 its nickname, “Orange Jumper”. Due to the ingenious design no flight test assignment has ever been cancelled because the J-066 instrumentation system wasn’t capable of measuring the required data. The J-066 has accumulated many flight test hours and has an impressive track record. A few of the many different kinds of flight test techniques have been selected to demonstrate the “Orange Jumper” versatility.

A schematic instrumentation overview is depicted in figure 1.

LIMIT CYCLE OSCILLATION (LCO) / FLUTTER TESTING

The F-16 can be used in many different roles, varying from a highly maneuverable dogfighter to a heavily loaded surface attack bomber. To achieve this variety the F-16 has to be capable of carrying many different combinations of wing- and fuselage stores (external tanks, weapons, targeting-, reconnaissance- and electronic countermeasure pods). One can imagine that placing so many different types of stores on a wing will have a large influence on aerodynamic, flying and handling qualities of the F-16. Most of these effects can be properly estimated and analyzed using Computational Fluid Dynamics (CFD) and other types of simulation.

Determining aeroelastic effects on the F-16 in different configurations is very complex. One of these effects is the occurrence of LCO during flight. LCO is an aeroelastic effect on the wing inducing a constant magnitude vibration in both wings, where the vibration in one wing is 180° out of phase with the opposite wing. LCO can be a prelude to flutter, in which case vibration magnitudes diverge exponentially with potential disastrous consequences. Since it is so difficult to compute aeroelastic effects, the majority of new store configurations is flight tested and configuration limits (airspeed and G-load) are determined through flight testing.

The Orange Jumper is ideally suited for this type of flight testing and has been used for this purpose many times over. Using the specially modified wing tip launchers equipped with two accelerometers each, wing tip accelerations can be accurately measured in flight. Flight test profiles start at relatively low airspeeds and with low G-loads, increasing both slowly working towards the, still unknown, limits. Accelerometer output from all sensors can be monitored in real-time on the ASHM. To be able to interpret data quickly and compare it with F-16 LCO limits, accelerometer data is processed in real-time using a Fast Fourier Transform (FFT). This technique enables the flight test engineer to have an in-flight visualization of the LCO frequency and its magnitude. Comparing these to specified F-16 LCO limits enables the ‘Orange Jumper’ to safely explore and set the limits for a specific store configuration.

Even though LCO can be monitored in real-time and compared to limits sometimes the unexpected still happens. Due to the unique features designed in the J-066 instrumentation system Lockheed Martin, and other international partners, regularly request flight test hours using the J-066. When in 2005 a new type of GBU-10 (2,000lbs laser guided bomb) was introduced, LCO testing was performed using the J-066. In cooperation with Lockheed Martin a flight test program was executed to determine carriage limits for this type of weapon. During this flight test the limit was most definitely found when, at some point in the flight envelope, vi-
brations aggravated suddenly. Due to the ability to monitor flight test progress in real-time the flight was aborted immediately upon detection of these aggravated vibrations. Safely back on the ground a visual inspection was performed and determined that part of the GBU-10 tail section was ripped off in-flight and damaged the aircraft (figure 2). Based on these test flights F-16 carriage speed and G-limits of the GBU-10 were modified worldwide to levels ensuring safety of flight.

STORE SEPARATION TESTING
Next to carrying weapons, tanks and multiple pod types, an F-16 should also be able to safely drop any given store from its wings. The reason the F-16 should be able to drop a variety of different types of bombs is quite obvious since one of the roles of the F-16 is to attack surface targets. In case of an emergency situation, e.g. engine failure, the F-16 is able to jettison all its wing stores with one single push action. Doing this will immediately decrease weight and drag and will improve overall performance, especially climb performance. It may be just the performance enhancement the pilot needs to be able to safely land the aircraft or to achieve more favorable ejection conditions if all else fails. Store configurations have carriage limits, but they also have employment (planned drops) and jettison (unplanned drops) limits.

Based on aerodynamic- and performance analysis store behaviour during its separation can be simulated quite accurately using six degrees of freedom (6DoF) store simulation models and models describing store interaction with the F-16 fuselage and store suspension equipment. Limits calculated using these models have to be verified by flight tests.

The “Orange Jumper” has been used for this purpose on numerous occasions equipped with the high speed cameras mentioned earlier. Stores to be jettisoned are painted in a special white and black pattern. Combining footage of all high speed cameras and using the special paint pattern a three dimensional store separation path can be reconstructed from the data (figure 3). This separation path can then be compared to simulation results and act as simulation model verification. Store separation flight testing remains a requirement for the J-066. External tanks separation behaviour, with varying quantities of fuel inside, is difficult to model.

RECECELITE F-16 SYSTEM INTEGRATION
A final example of F-16 flight testing in the Netherlands is the integration of the RecceLite Aerial Reconnaissance Pod (ARP) with the RNLAF F-16. RecceLite is a Rafael product and is capable of providing high resolution aerial images in both the visual and infrared spectrum and sending them to a ground based analysis station using a high bandwidth data link. The RNLAF was the first customer to integrate RecceLite on the F-16 and its avionics architecture. Cooperating closely with DMO, NLR, Lockheed Martin and Rafael the J-066 MIL-STD-1553 recording capability was used to ease RecceLite integration with F-16 systems.

PAST, PRESENT AND FUTURE F-16 FLIGHT TESTING
Apart from the few examples described in this article many other new and innovating solutions have been developed, flight tested and adopted in the F-16’s long history. To remain a top of the bill aircraft it is expected that more and more flight testing will be needed in the future. New operational requirements will impose more and increasingly difficult challenges to engineers, since ever less space is available in the ageing aircraft to integrate new avionics and systems. Eventually the F-16 will be phased out and replaced by a different aircraft. Until that day the J-066 “Orange Jumper” and the entire F-16 flight test team will be around to fulfil all flight test requirements.

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