Design Space Exploration of a High Altitude Aerial Platform, “Mothership”

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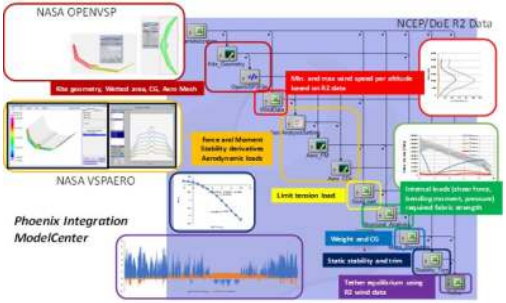
A global Toyota research team is investigating the feasibility of a futuristic high altitude aerial platform concept (called Mothership), envisioned to be reconfigurable to a variety of applications such as wind energy harvesting, atmospheric data acquisition, high speed communication relay, and payload transportation [1]. As a part of this endeavour, a preliminary system level analysis was conducted to gain initial insight into key system attributes as well as sensitivities with respect to design and technology parameters.
An integrated design and analysis environment was created by harnessing fast analysis tools covering key disciplines such as wind data, aerodynamics, inflatable structural analysis, mass properties, kite stability, and tether catenary. To expedite the design space exploration, a set of surrogate models was created from the integrated multi-disciplinary tool. Utilizing the surrogate models, a Monte Carlo simulation was performed to generate 30,000 different designs. The feasibility of those designs was evaluated against a set of design requirements including the internal pressure of the inflatable structure, kite stability, and tether tension. A baseline design, selected from a Pareto front, was further evaluated for impacts of design altitude and advanced technologies. This preliminary analysis indicates that access to high altitude (10km) requires a significantly large and lightweight kite and tether construction. In addition, advanced technologies are necessary for reliable operation at high altitudes. To cope with a wide seasonal variation of wind speed, advanced actuation system appears to be highly desired for stability augmentation, load alleviation and flutter suppression.



Integrated design and analysis environment for high altitude aerial platform concept design. OpenVSP was used to define wing geometry and to estimate wetted area. VSPAero was used to predict aerodynamic properties. Wing structure was approximated to a cantilever beam and analysed based on Euler beam theory. Once a kite design is defined, it was determined whether the kite can stay at 10km altitude for a variety of wind speed profiles derived from NCEP/DoE R2 data accounting for drag and weight of a tether.

References:

[1] Itakura E.: Save from Future Japan Social Crises! "Mothership" Project, AWEC, Glasgow, UK, 15-16 October 2019 (AWEC No. 65)