Titan WIG
Frank

Problem Definition

Objective

- Design a WIG Craft for planetary surface exploration
- Estimate performance on the atmosphere in Titan

Constraints

Performance requirements:

- Range to exceed 10 km
- Dry mass = 450 Kg (with Battery)

Power Assumptions

- Hotel Power = 100W
- Battery density = 100 W.hr/kg

Titan - Features

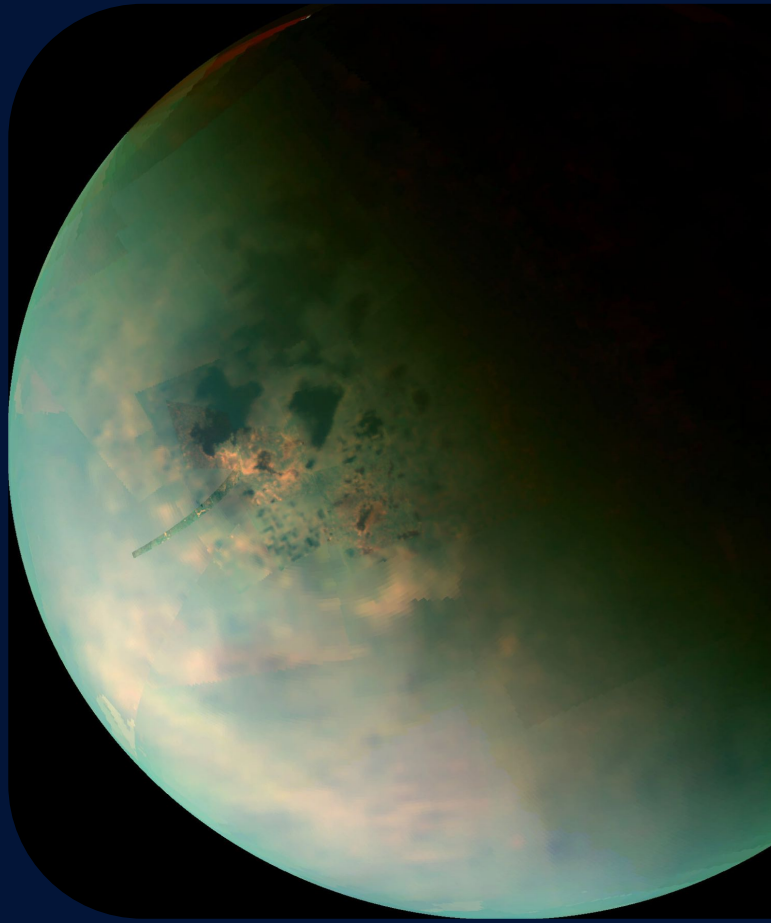
Saturn's Largest moon

Acceleration of Gravity
- 1.4 m/s^2

Distance from Sun
- 1,427,000,000km
- Sunlight 100X weaker than on Earth

Speed of Sound
- 194 m/s

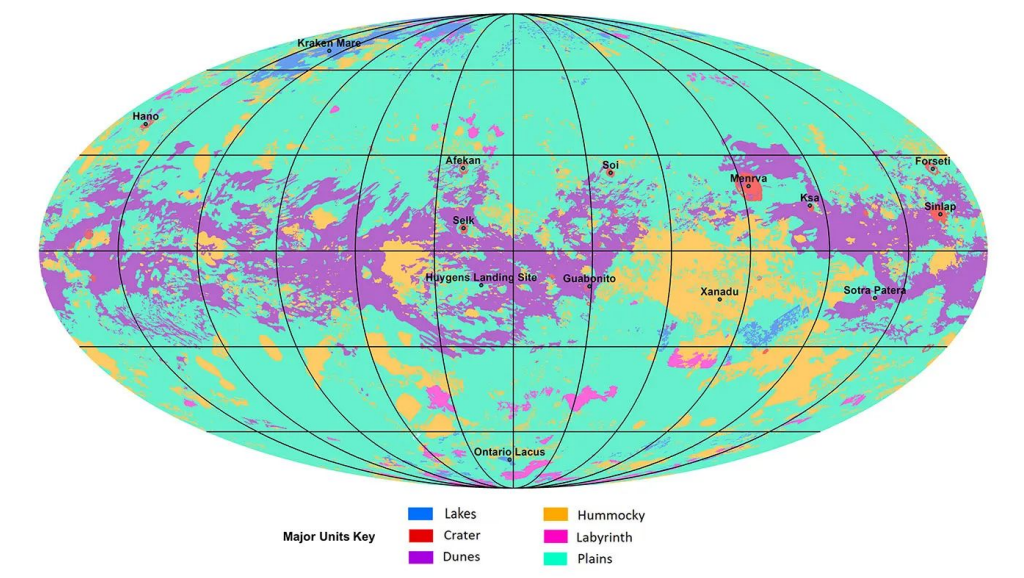
Radius
- 2,575 km



Titan's dense, hydrocarbon rich atmosphere remains a focal point of scientific research. Credit: NASA

Titan - Surface

- 67% - flat plains
- 17% - sandy dunes (mostly around the equator)
- 14% - ‘hummocky’ — hilly or mountainous
- 1.5% is ‘labyrinth’ terrain, with valleys carved by rain and erosion



TITAN - Atmosphere

Composition
- Nitrogen [94%] & Methane [6%]

Surface Pressure
- 146 kPa [3050 lb/ft^2]
  - 50% higher than earth

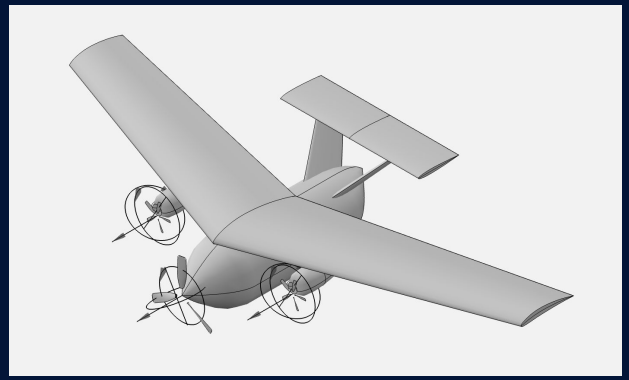
Surface Temperature
- 94° K
- -180° C
- -290 °F

Density
- 5.4 kg/m^3
  - X4.4 earth density

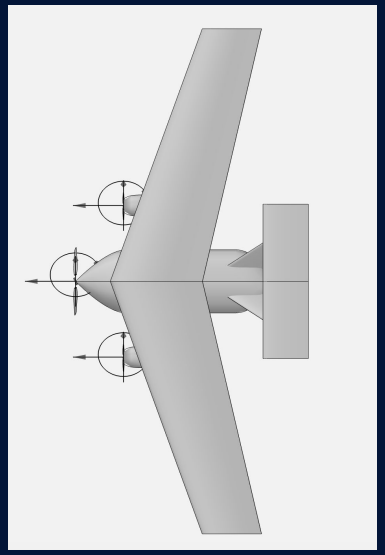
Layers of Titan atmosphere, image from the *Cassini* spacecraft

Design Features and Impact

Concept Picture



Isometric View



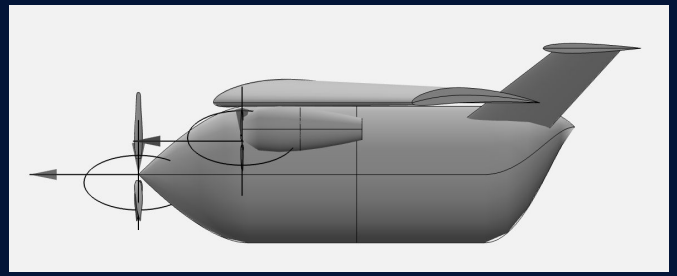
Top View

Wings

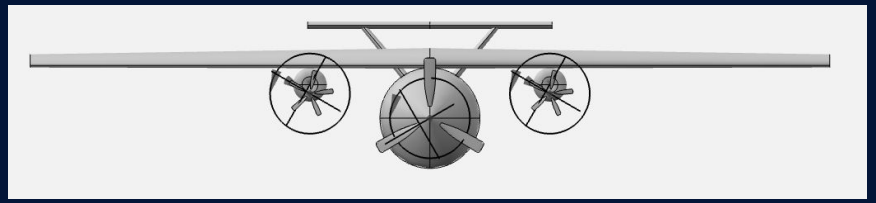
- Span : 10m
- Aspect Ratio : 6.6
- S : 15m^2
- Sweep : 20°

Fuselage

- Length : 4m
- Diameter : 1.5m



Side View

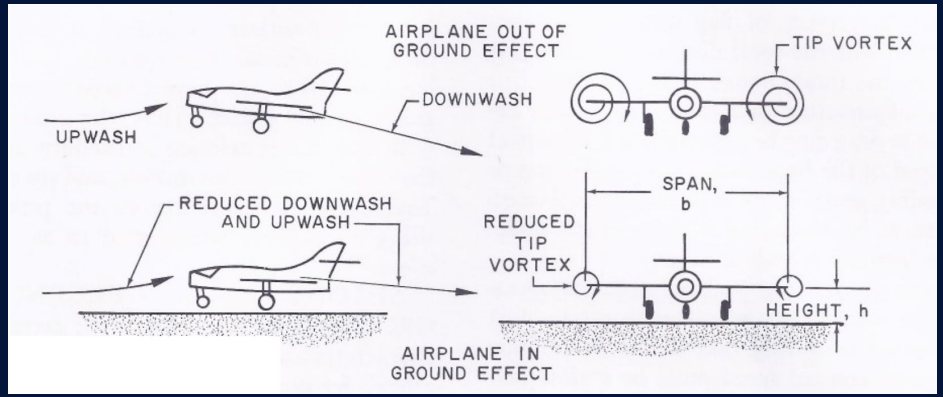


Front View

Design Philosophy and Selection Criterion

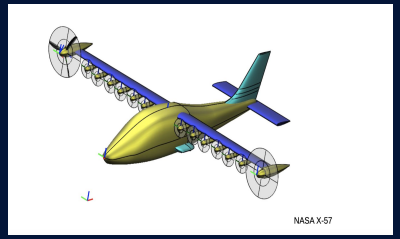
Why WIG?

- Reduced wing tip vortices
  - Decreased induced drag
  - Higher speeds
  - Lower power requirement
- Increased pressure beneath wings
  - Increased lift
  - Lower power requirement
  - Larger payload capabilities

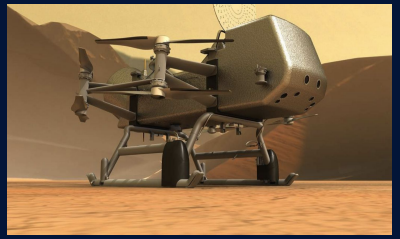


Inspirations

X-114 Lippisch
WIG



Maxwell X-57



Titan Dragonfly
NASA Image

Widgetworks

DARPA Liberty Lifter
Concept(General
Atomics Image)

Unique Features of Concept

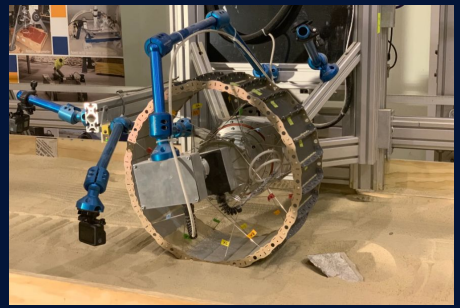
Folding

- The wings fold inwards so that the aircraft can be transported to Titan. Each wing has two folds
- Fit inside aeroshell that is 4.5 meter diameter
- Vehicle mostly wing, small fuselage

Mars 2020 Aeroshell, NASA

Wheels

- Aluminum Alloy 7075 - high fatigue resistance and maintains mechanical properties at low temperatures.
- Inspiration taken from NASA's VIPER



NASA VIPER wheel design

Electric Propulsion

- No need for fuel which runs out, increases lifespan

Impact

Environment

- Tech/instruments can also analyze Earth
  - More nuanced understanding of our own environment
- Utilizing electric propulsion therefore developing better electric technology that could be used on Earth

Economy

- Provide many jobs for years
  - Manufacturing/fabrication
  - Development/design

Impact

Society

- Heightened interest in space exploration
- Tech breakthroughs to benefit all
- Spinoff technologies - NASA reported +2000 since 1976

The World

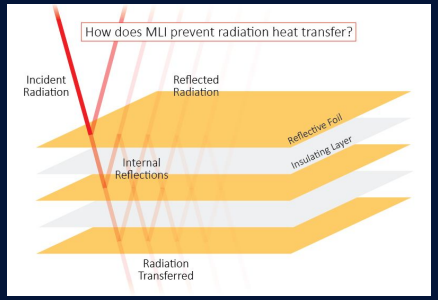
- Further our knowledge of the universe as a whole
- Help to develop technology that benefits us on Earth
- Potential for life helps understand life on Earth

Technical Risk

Structures

Insulation

- Multilayer Insulation (MLI) System
  - Sandwich structure of reflective, spacing and insulating, as well as adhesive materials
  - Prevents radiation in/out of spacecraft to maintain operating temperatures



- Advantages
  - Ensure functionality/longevity of onboard systems/instrumentation
  - Lightweight
  - Functionally efficient (nearly 100% reflection of radiated heat)
  - Energy efficient (less need for venting/heating)
  - Able to fit complex geometries (built for purpose in every case)
  - Enhanced structural integrity (reduced thermal cycling)

Structures

Materials

- Aluminum Alloy 2024-T3 - Fuselage, Tail, Wings
  - Has a high strength-to-weight ratio
  - High fatigue resistance
  - Strong in cold temperatures

Mass Estimates

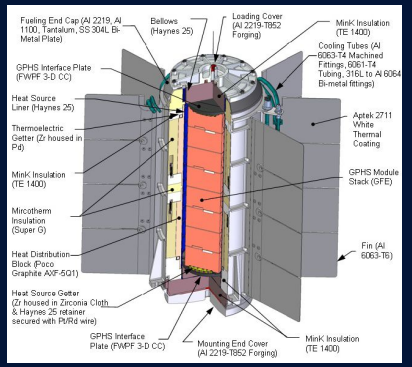
- 140 kg - Battery
- 45 kg - MMRTG Generator
- 81 kg - Propellers
- 25kg - SubSystems
- 13.5kg - Wheels (4.5kgX3)
- 145.5kg - Structure

Total - **450kg**

Propulsion

Power Generator: MMRTG
Multi-Mission Radioisotope ThermoElectric Generator

- ~75W (after degradation, at BOL 110W)
- Approx 4.5W loss a year
- Generates heat for internal system



MMRTG Generator NASA Image

Battery:

- 100 W.h/kg
- Sized to be 140 Kg
- Complete battery charge in 192 hours (1 Titan Night)
- 75W x 192h = 14.4kWh

*inspired by Dragonfly

Propulsion

Propellor type 1 (small) x2

- MH 114
- D = .58m
- 5 blades
- Fixed Pitch

Propellor type 2 (large) x1

- MH 114
- D = 1.5m
- 3 blades
- Fixed Pitch

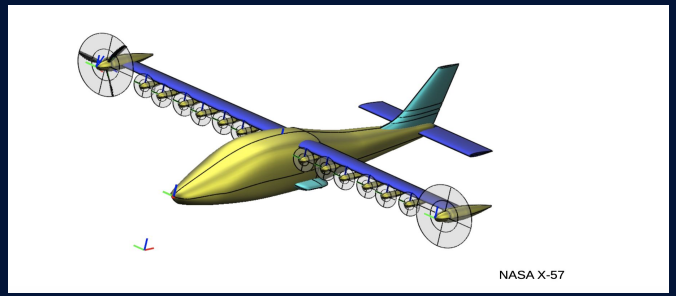
*based on propulsion from X-57 Maxwell

Motor type 1 (electric cruise motor) x2

- Power requirement: 10.5kW
- Efficiency Factor: .98
- Mass = 7 kg

Motor type 2 (electric high lift motor) x1

- Power requirement: 60kW
- Efficiency Factor: .98
- Mass = 53 kg



Maxwell X-57

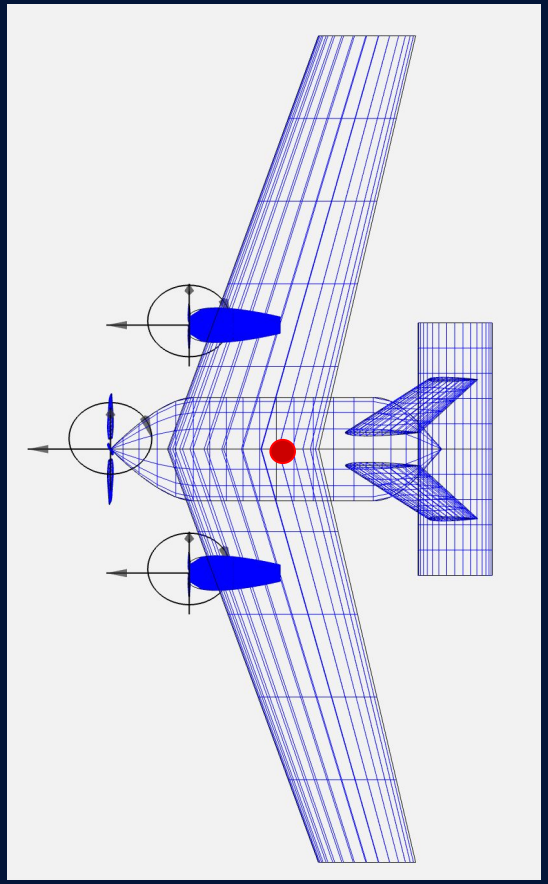
Stability and control

Static Stability

- Batteries located at CG location

Dynamic Stability

- T-tail design reduces turbulence which is important for WIG aircraft
  - Provides horizontal and vertical stability
- PID controller controls ailerons and elevator/rudder
- High wing placement increases roll stability



Craft top view with CG Location

SubSystems

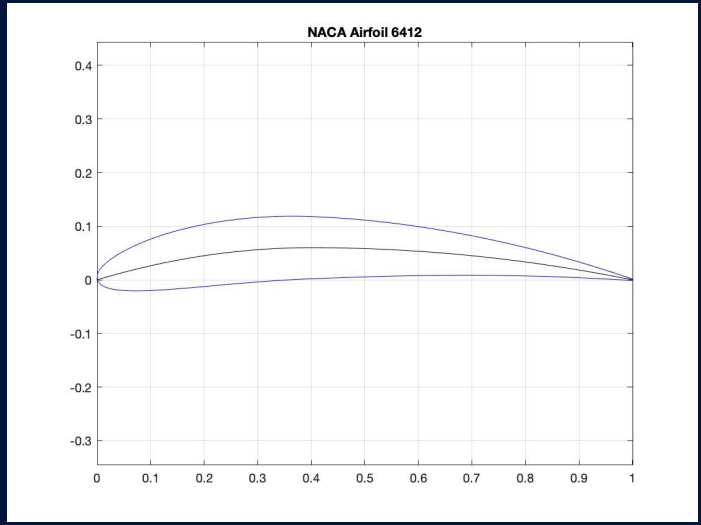
- **Mass Spectrometer**
  - Determine chemical composition
- **Gamma-Ray and Neutron Spectrometer**
  - Determine composition of area below lander
- **Geophysics and Meteorology Package**
  - Temperature
  - Wind speed
  - Pressure
  - Tectonic Activity
- **Camera Suite**
  - Provide images of Titan surface
  - Navigate using cameras and data from previous Titan exploration

*Based on dragonfly

Aerodynamics

Airfoil choice 6412

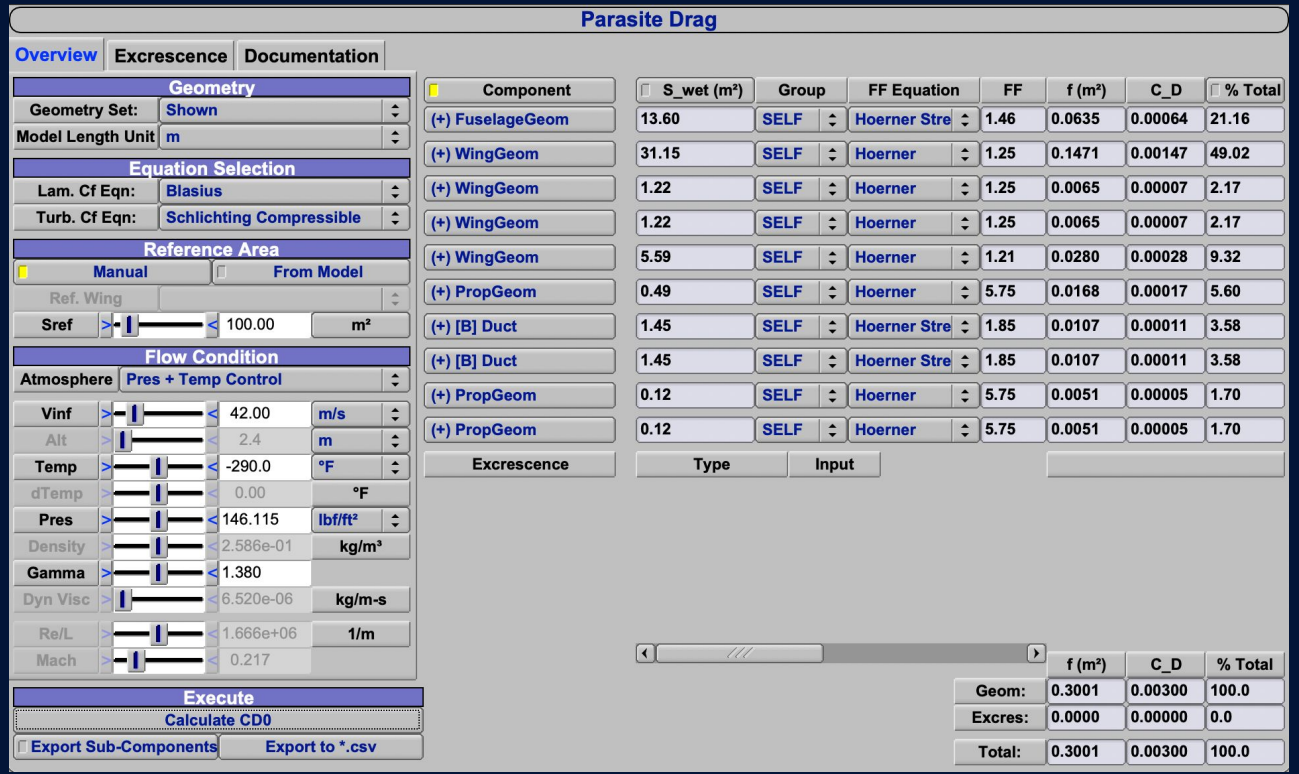
- Cambered airfoils capable of generating lift even at 0° angle of attack
- Optimizes lift/drag ratio
- High camber contributes to larger pressure drop



*informed by CFD Analysis(see Journal of Physics reference)

Aerodynamics - Parasitic drag

C_{DO} = .003



Aerodynamics - Drag Polar

$C_{Di} = K C_L^2$

$.072 = K\ 0.96^2$

$K = .0781$

*No WIG effects

$C_{Diwig} = .072*.7 = .0504$

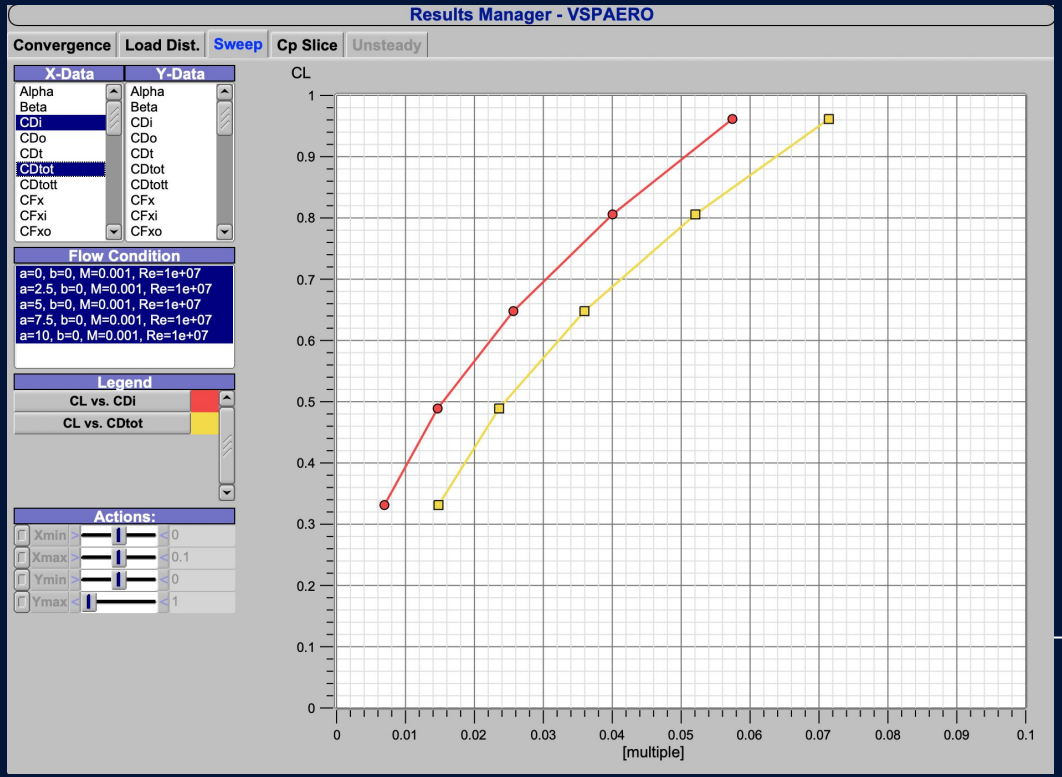
$.0504 = K\ 0.96^2$

$K = .05468$

*WIG effects included

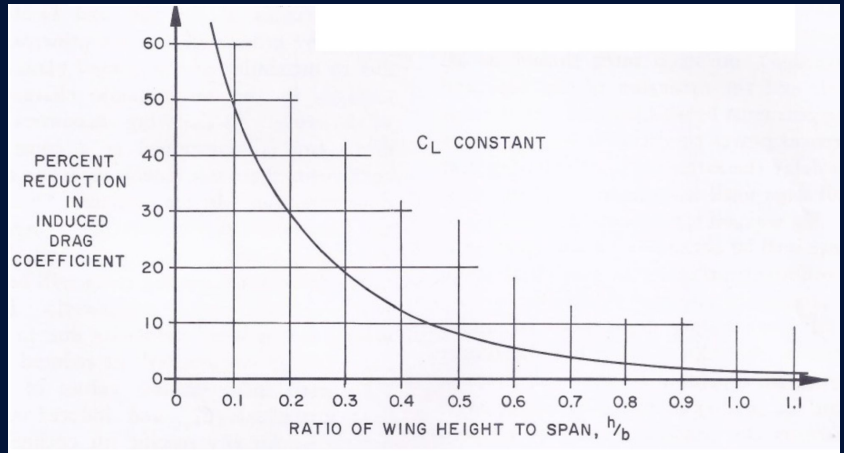
K - lift-induced drag coefficient factor

C_{Di} - induced drag coefficient



Flight Mechanics

- Range : 41 km
- Altitude : ~2m (20% of span)
- Cruise Speed: 55 m/s
- Mach: .28
- Flight Duration: 12 minutes
- Large Aspect ratio : 6.6
    - Maximize height off the ground to use WIG effect
    - Increase oswald efficiency factor
    - Drawback: less maneuverable but Titan is very flat so not a big factor



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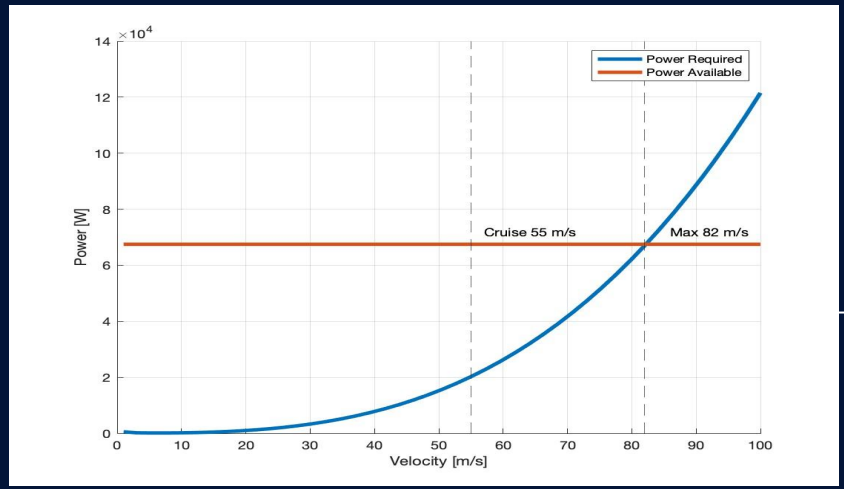

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QUESTIONS?