

Titan WIG Frank

Group 6

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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

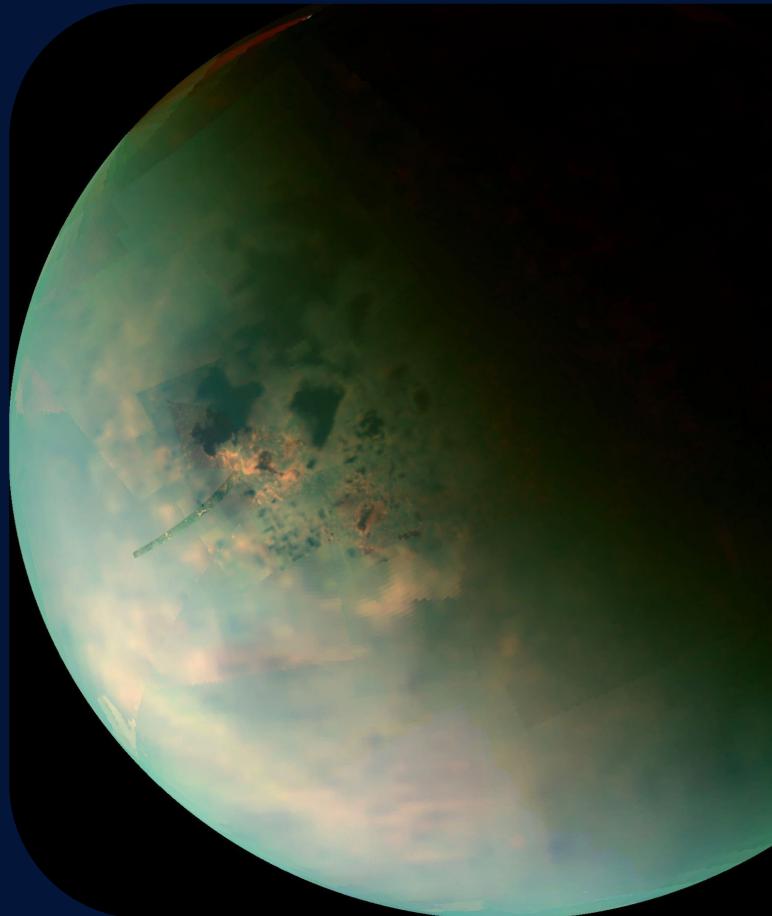
- 1,427,000,000km
- Sunlight 100X weaker than on Earth

Speed of Sound

- 194 m/s

Radius

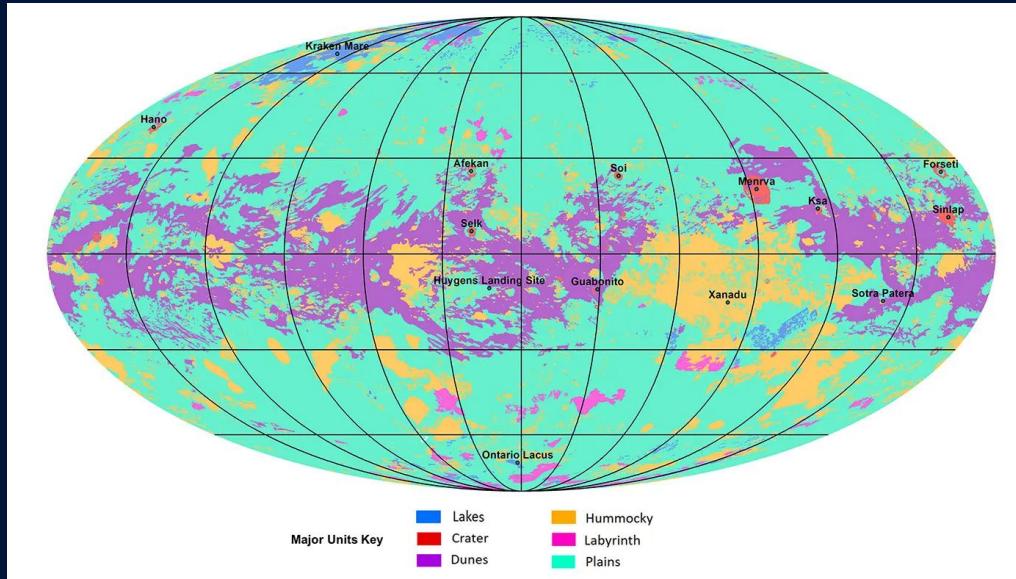
- 2,575 km



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

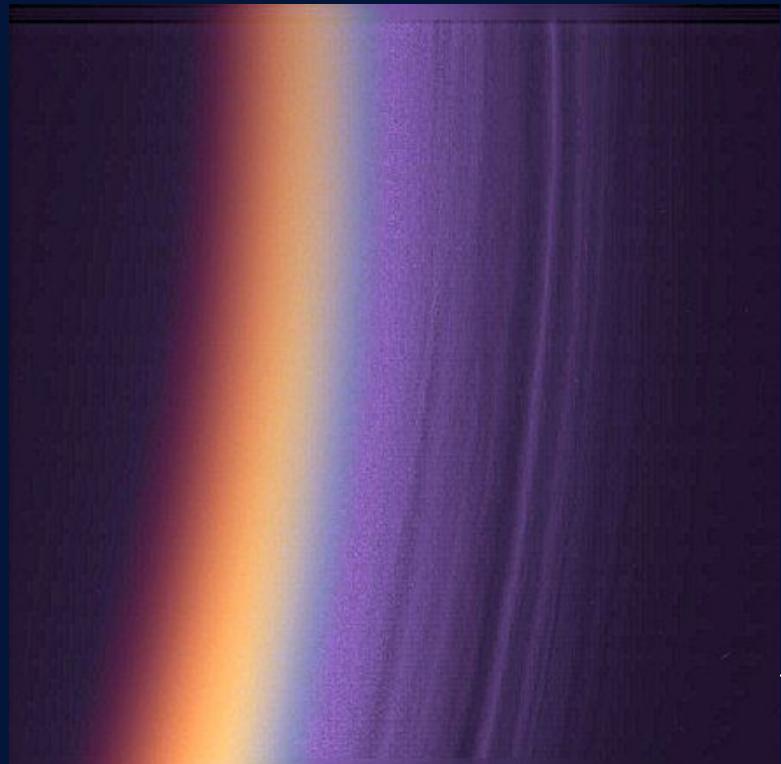
- 146 kPa [3050 lb/ft²]
 - 50% higher than earth

Surface Temperature

- 94° K
- -180° C
- -290 °F

Density

- 5.4 kg/m³
 - X4.4 earth density



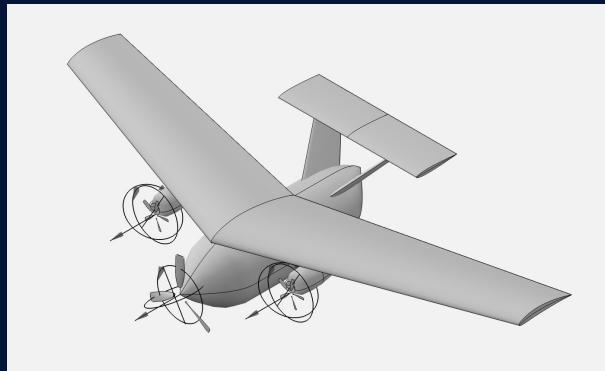
Layers of Titan atmosphere, image from the *Cassini* spacecraft

Design Features and Impact

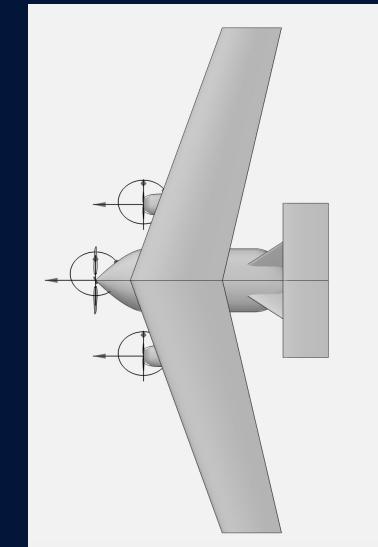




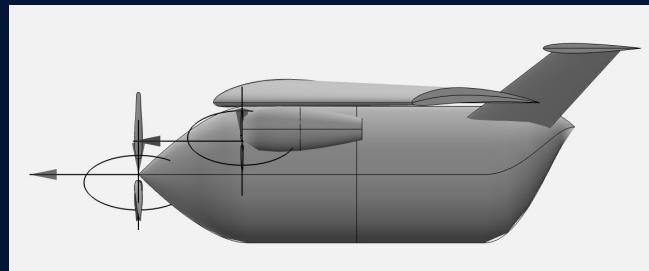
Concept Picture



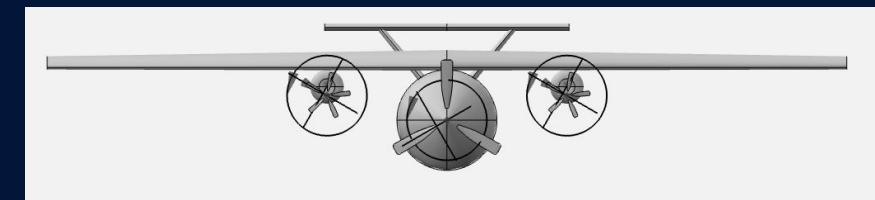
Isometric View



Top View



Side View



Front View

Wings

- Span : 10m
- Aspect Ratio : 6.6
- $S : 15\text{m}^2$
- Sweep : 20°

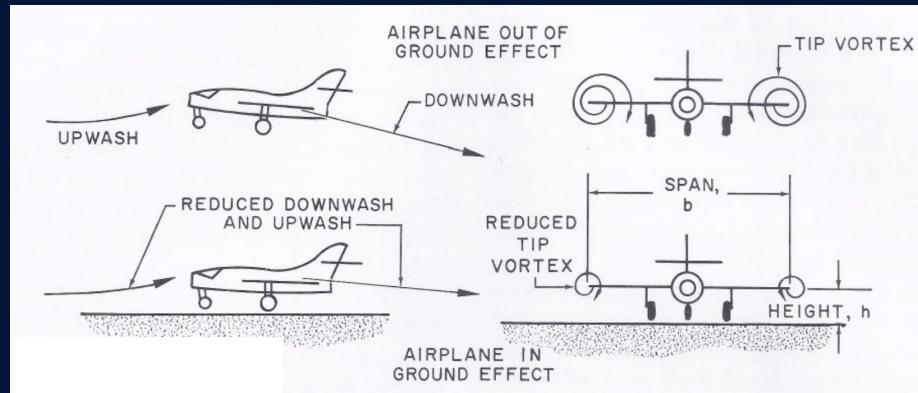
Fuselage

- Length : 4m
- Diameter : 1.5m

Design Philosophy and Selection Criterion

Why WIG?

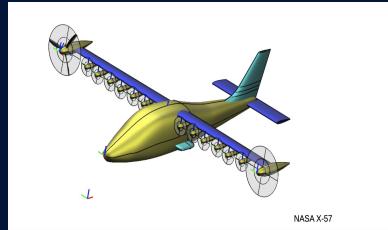
- Reduced wing tip vortices
 - Decreased induced drag
 - Higher speeds
 - Lower power requirement
- Increased pressure beneath wings
 - Increased lift
 - Lower power requirement
 - Larger payload capabilities



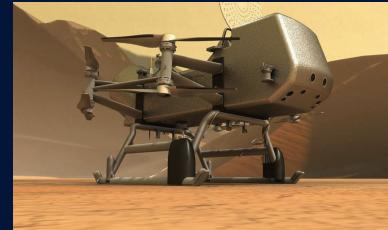
Inspirations



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

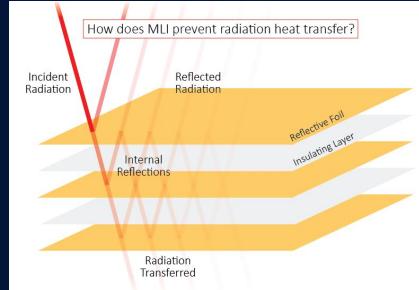


Technical Risk

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

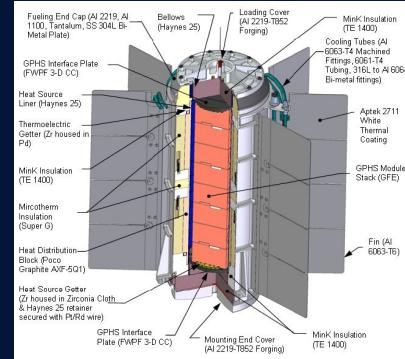


Propulsion

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)
- $75\text{W} \times 192\text{h} = 14.4\text{kWh}$

*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

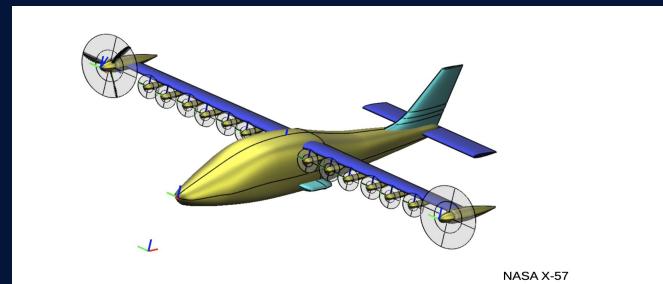
*based on propulsion from X-57 Maxwell

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



NASA X-57

Maxwell X-57

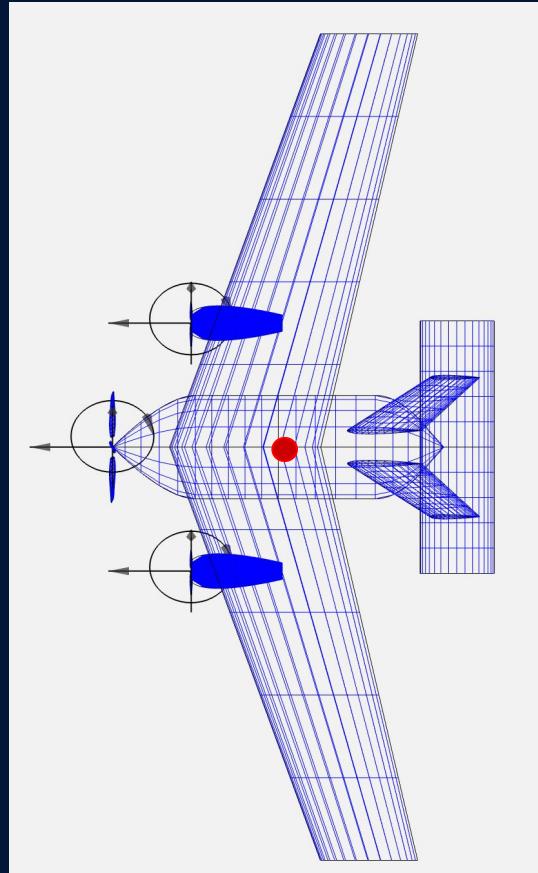
Stability and control

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

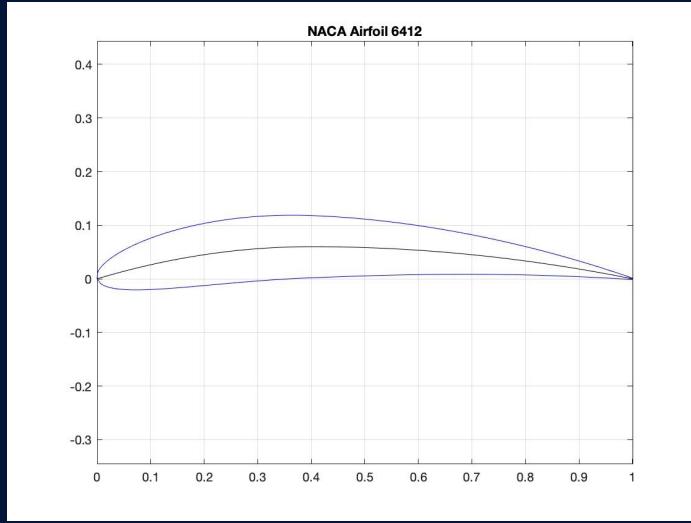


Aerodynamics

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

$$C_{D0} = .003$$

Parasite Drag

Component	S_wet (m ²)	Group	FF Equation	FF	f (m ²)	C_D	% Total
(+) FuselageGeom	13.60	SELF	Hoerner Stre	1.46	0.0635	0.00064	21.16
(+) WingGeom	31.15	SELF	Hoerner	1.25	0.1471	0.00147	49.02
(+) WingGeom	1.22	SELF	Hoerner	1.25	0.0065	0.00007	2.17
(+) WingGeom	1.22	SELF	Hoerner	1.25	0.0065	0.00007	2.17
(+) WingGeom	5.59	SELF	Hoerner	1.21	0.0280	0.00028	9.32
(+) PropGeom	0.49	SELF	Hoerner	5.75	0.0168	0.00017	5.60
(+) [B] Duct	1.45	SELF	Hoerner Stre	1.85	0.0107	0.00011	3.58
(+) [B] Duct	1.45	SELF	Hoerner Stre	1.85	0.0107	0.00011	3.58
(+) PropGeom	0.12	SELF	Hoerner	5.75	0.0051	0.00005	1.70
(+) PropGeom	0.12	SELF	Hoerner	5.75	0.0051	0.00005	1.70

Excrescence **Type** **Input**

Geom:	0.3001	0.00300	100.0
Excres:	0.0000	0.00000	0.0
Total:	0.3001	0.00300	100.0

Geometry

Geometry Set: Shown
Model Length Unit: m

Equation Selection

Lam. Cf Eqn: Blasius
Turb. Cf Eqn: Schlichting Compressible

Reference Area

Manual From Model

Ref. Wing
Sref > 100.00 m²

Flow Condition

Atmosphere Pres + Temp Control

Vinf > 42.00 m/s
Alt > 2.4 m
Temp > -290.0 °F
dTTemp > 0.00 °F
Pres > 146.115 lbf/ft²
Density > 2.586e-01 kg/m³
Gamma > 1.380
Dyn Visc > 6.520e-06 kg/m-s
Re/L > 1.666e+06 1/m
Mach > 0.217

Execute

Calculate CD0

Export Sub-Components Export to *.csv

Aerodynamics - Drag Polar

$$C_{Di} = K C_L^2$$

$$.072 = K 0.96^2$$

$$K = .0781$$

*No WIG effects

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

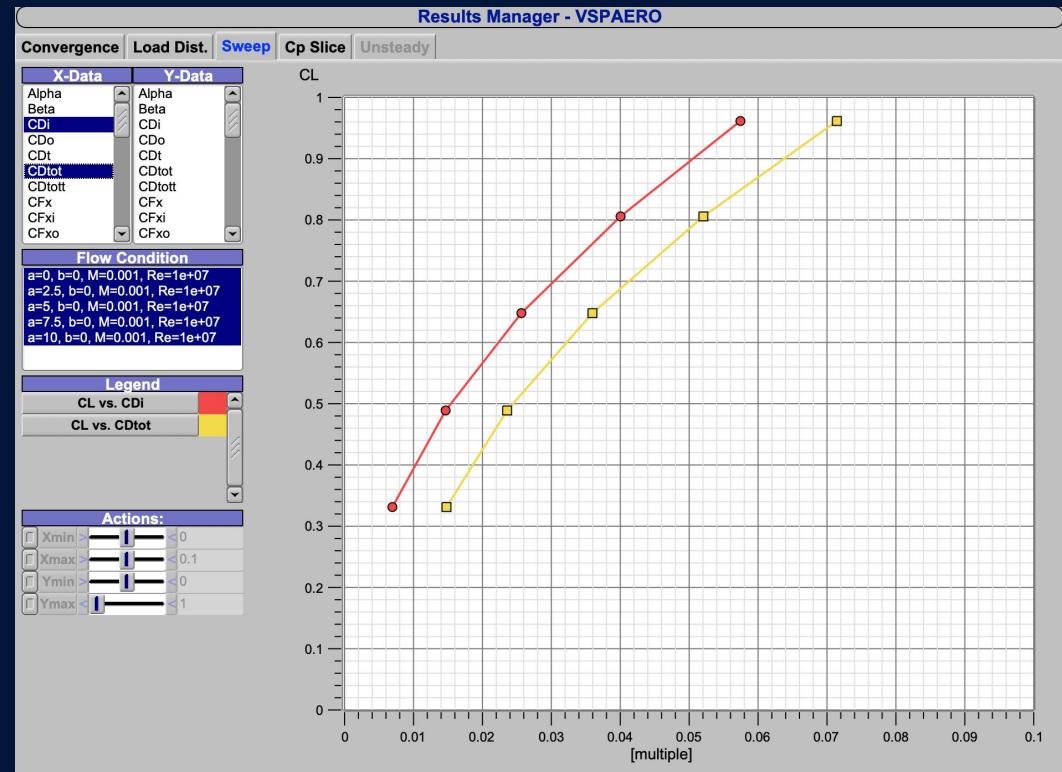
$$.0504 = K 0.96^2$$

$$K = .05468$$

*WIG effects included

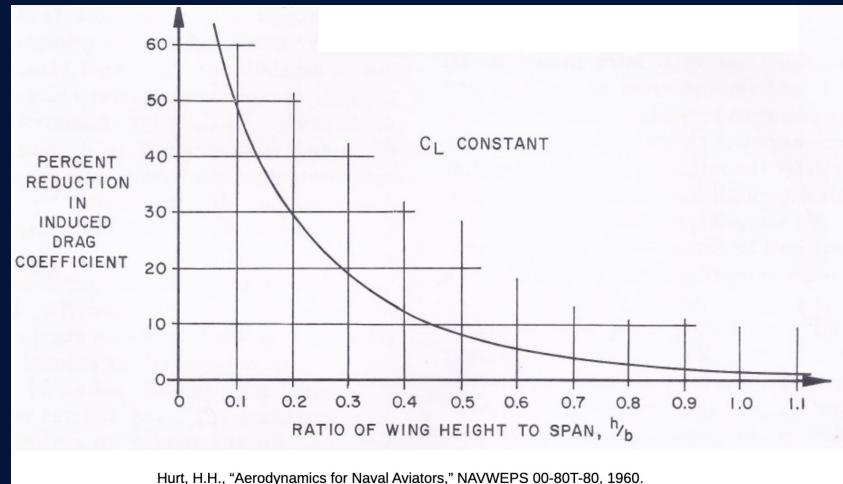
K - lift-induced drag coefficient factor

C_{Di} - induced drag coefficient

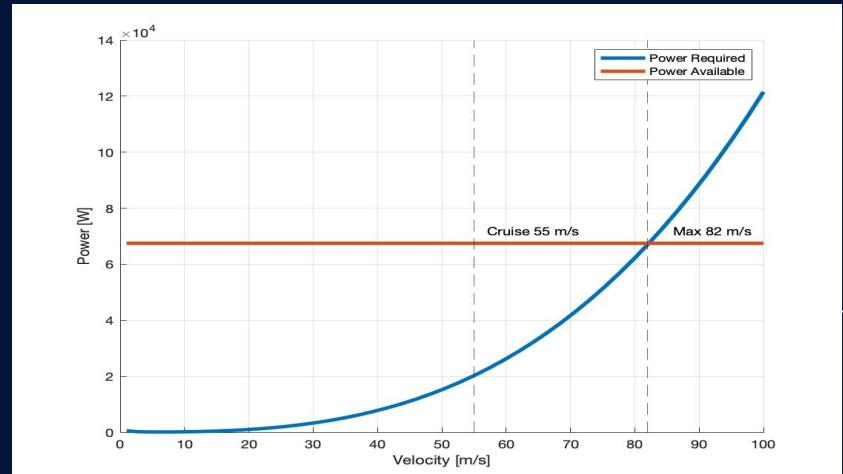


Flight Mechanics

- 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



Hurt, H.H., "Aerodynamics for Naval Aviators," NAVWEPS 00-80T-80, 1960.



References

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<https://www.nasa.gov/solar-system/artemis-moon-rovers-wheels-are-ready-to-roll/> (wheel design)

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QUESTIONS?

