Conceptual Design of UAV for Titan Exploration

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Why Titan?

• Titan exhibits attributes more similar to Earth than any other body in the solar system.
  • Can show us how life might have come about on Earth
• UV light breaks down nitrogen and methane molecules, and they recombine to form organic molecules, which are the basis of life itself.
About Titan

• Atmosphere is 95% Nitrogen, <5% Methane
• Reservoirs of liquid methane
• Hydrocarbon cycle similar to Earth’s water cycle
• Atmospheric density is 5.4 kg/m³
• Only moon with a thick atmosphere
• Surface gravity is 1.35 m/s²
Mission Requirements

- Perform aerial and deep sea mapping
- Amphibious
- Collect and analyze samples for biochemical assessment
- Measure change in chemical composition
- Track current behavior of liquid bodies
- Examine differences between lakes and seas
Vehicle System Requirements

• Direct transmission of data to Earth
• One onboard Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) with periodic charging of lithium-ion battery
• Take off and land on solid and liquid surfaces
• Different speed of rotors for the two different environments
Drafts of UAV
Scientific Instrumentation

• Mass Spectrometer similar to Dragonfly’s (DraMS)
• Ultrasonic sensors (SONAR)
• Light Detection and Ranging (LiDAR)
• Cameras
• Geophysics and Meteorology Package similar to DraGMet
  • COTS Sensors – atmospheric pressure and temperature
  • Thermal anemometers – direction and speed of wind
  • Differential near-IR abundance – humidity
Final Design of UAV
3D Printed 1/10th Scale
Functional Decomposition of UAV
Aerial and Submersible UAV

**Arm**
- Claw to analyze while holding sample by using micro-technology
  - Cause suction: low air pressure, vacuum/fan
  - Organizing internal components
d- Designed to minimize drag
  - Small wake region
- Suction to collect samples

**Body**
- Way of transporting
  - Internal analysis chamber
  - Similar to SAM (Sample Analysis at Mars)
- Internal components
  - Figure out a way to dispose of samples
  - Encoder in motor (tells how much to rotate)

**Rotors**
- Rotor mount rotation 90 to horizontal position
  - Spin coaxially to eliminate angular momentum
  - Lock into thrust-bearing support
- Adequate power supply to handle current draw
  - Power from battery, which is charged by MMRTG

**Landing Gear**
- Land on surface
  - Thick layer underneath pontoon
- Land on liquid methane
  - Floatation device: pontoon with ballast tank
- Lead screw
  - How will it rise out of lakes/sea?
Mission Profile of the Four Phases
Phase A: Aerial Flight

- Vertical Takeoff followed by ascent at 20°
- Hover
- Forward Flight: Image Terrain

- Transition to Ascent at 20°
- Land
- Descent
- Ascent
- Recharge
- Forward Flight: Image Coastline

- Depart Initial Landing Site (60 km north of Jingpo Lacus exploration site)
- 60 km
- 73°N 336°W
- 85 km
- Range
- Coast Line
- Hover, Reverse direction, Began retreat
Phase B: Jingpo Lacus Exploration

Vertical Takeoff
Transition to Ascent at 20°

500 m
50 m

Recharge

Subsea Descent
Data Collection:
Pressure and Temperature Sensors Active

Land/Sea Boundary

Depart 73°N 336°W

Forward Flight: Retreat

Dive 1: 2 m
Dive 2: 3 m
Dive 3: 5 m

Vehicle begins retreat at predetermined battery level

Subsea Forward Motion
Sample Collection:
Liquid Sampler Active
Sonar Imaging

Range
Phase C: Jingpo Lacus to Kraken Mare Transition Flight

Forward Flight

Altitude

500 m

Day 1
Recharge 55.5 km
Depart Jingpo Locus 73°N 336°W

Day 2
Recharge 111 km
Vertical takeoff followed by ascent at 20°

Day 3
Recharge 166.5 km

Day 4
Recharge 222 km

Day 5
Recharge 277.5 km

Day 6
Recharge 333 km

Day 7
Recharge 388.5 km

Day 8
Recharge 445 km

Range

Arrive Kraken Mare 68°N 310°W
Phase D: Kraken Mare Exploration

Vertical Takeoff Transition to Ascent at 20°

500 m

50 m

Recharge

Subsea Descent Data Collection: Pressure and Temperature Sensors Active

Dive 1: 15 m

Dive 2: 30 m

Dive 3: Maximum Depth

Subsea Forward Locomotion Sample Collection: Liquid Sampler Active Sonar Imaging

Range

Vehicle begins retreat at predetermined battery level

Land/Sea Boundary

Depart 68°N 310°W
TITAN LACUS & MARE EXPLORATION
The second generation of Titan explorer drifting thru the sea and lake...

1. Take off and forward flight
2. Land to subsea transition
3. ...
4. Subsea to land transition
5. Ascending and hover
Analysis of UAV
Main Body Insulation

The cross section of UAV wall consists of two 2.5 cm thick layers of titanium on both sides of a layer of aerogel insulation.
Analysis using RotCFD

Flow visualization of UAV in aerial flight

Flow visualization of UAV in subsea locomotion
Exaggerated view of deformation from large drag force on connection of rotor hubs to fuselage

- If UAV were to suddenly accelerate upwards, it could experience 20 Newtons of drag force
- Total displacement is $1.14 \times 10^{-6}$ m
Future Work

• Autonomous code for flight operation
• Detailed design of the individual mechanisms and motors
• Improve accuracy of the sizing of individual components and designing an effective arrangement of these components to result in an optimal CG
• Further thermal analysis
• Vibration testing to simulate dynamic events that occur during launch and powered flight
Thank You!!

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References