# A Preliminary Design for the InSPiRESat-1 Mission and Satellite Bus:

## Exploring the Middle and Upper Atmosphere with CubeSats

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# INternational Satellite Program In Research and Education


- Objectives:
  - CubeSat constellation for Earth and Space Science Research
  - Global ground station network
  - Academic program in mission & spacecraft design, operations, and data analysis.

# Middle & Upper Atmosphere

THERMOSPHERE

~ 85 km

MESOSPHERE

~ 60 km

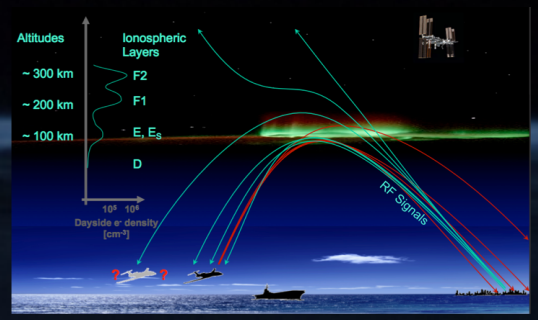
STRATOSPHERE

~ 20 km

TROPOSPHERE

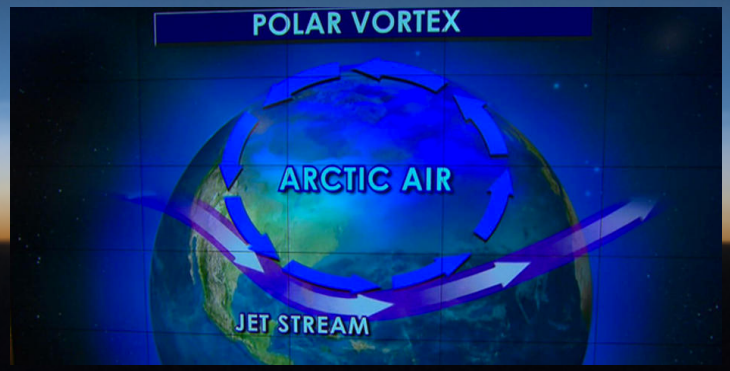
You are here

Satellite Drag
Reentry Dynamics




Ionospheric Variability
Communications

Stratospheric Polar Vortex
Weather Prediction



THERMOSPHERE

~ 85 km

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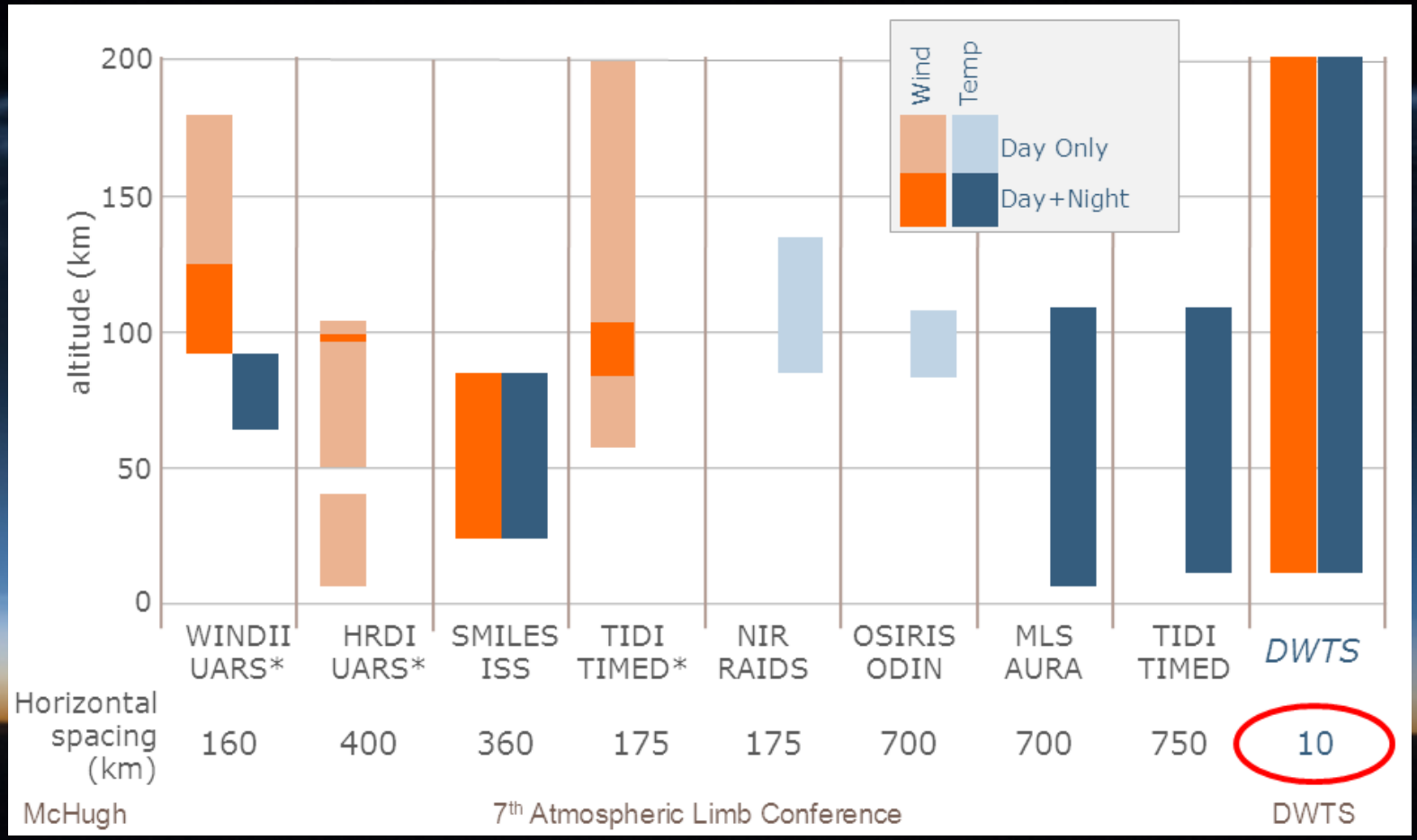
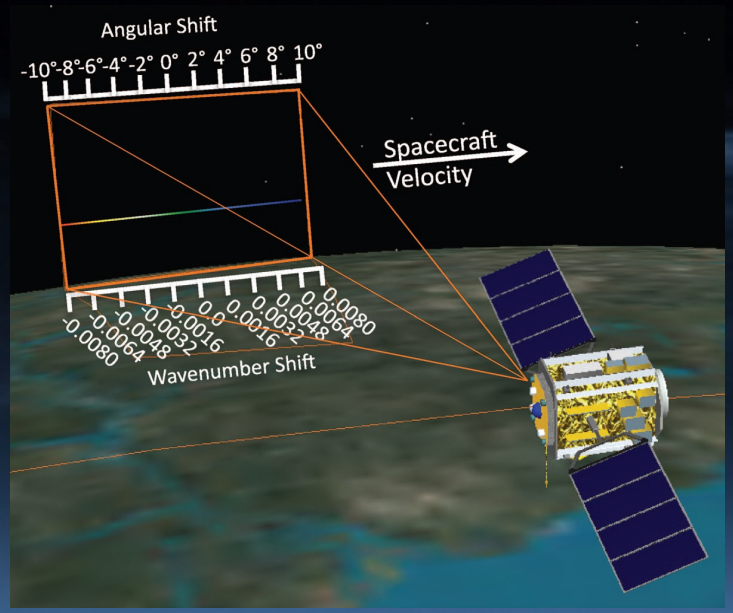
# Limited Observational Ability




Gordley et al., SPIE 2013

# Doppler Wind and Temperature Sounder



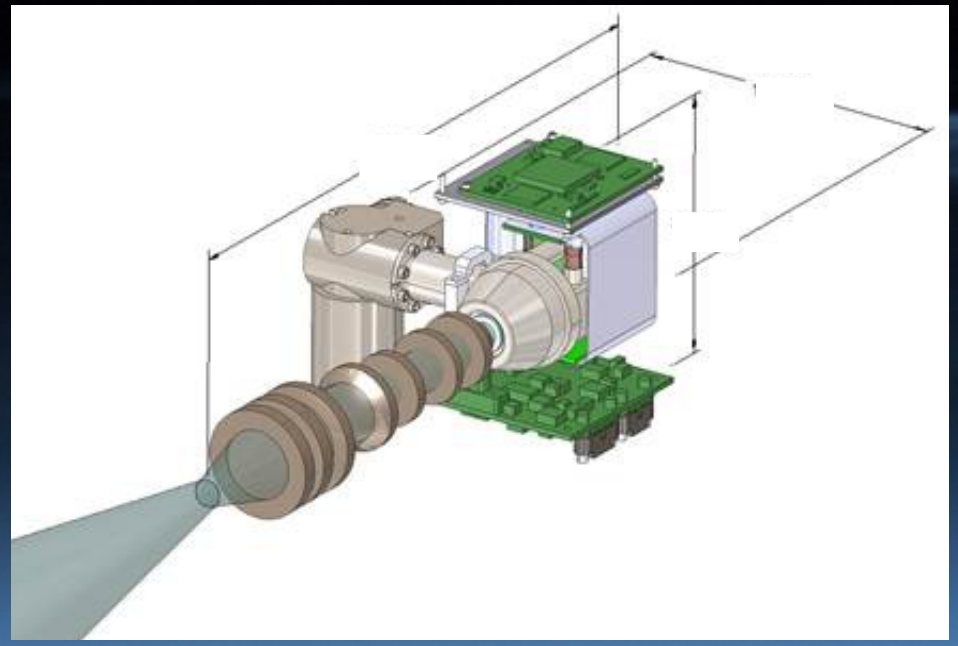

Limb scan of NO emissions

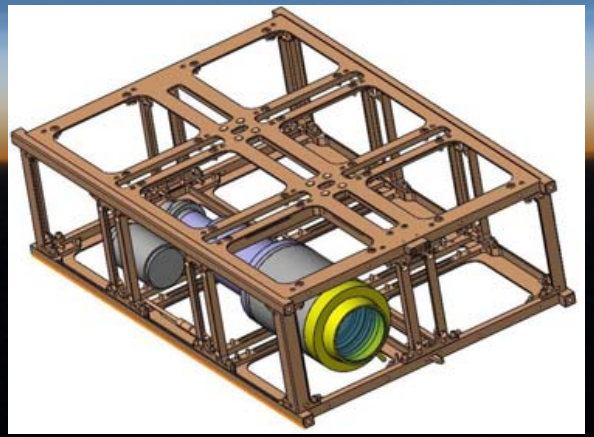
Doppler shift and width of emission lines

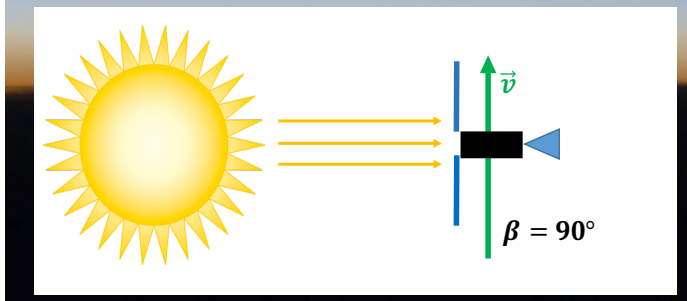
Atmospheric winds and temperature from 30 to 200 km

- New gas filter correlation radiometer measurements of wind and temperature (~25 – 250 km)
- Cross-track limb pointing IR camera with cryocooler. Processor for data aggregation.
- Designed and patented by GATS. Fabrication by University of Colorado LASP.
- Still requires operational heritage in space environment (TRL 4).

# Doppler Wind and Temperature Sounder

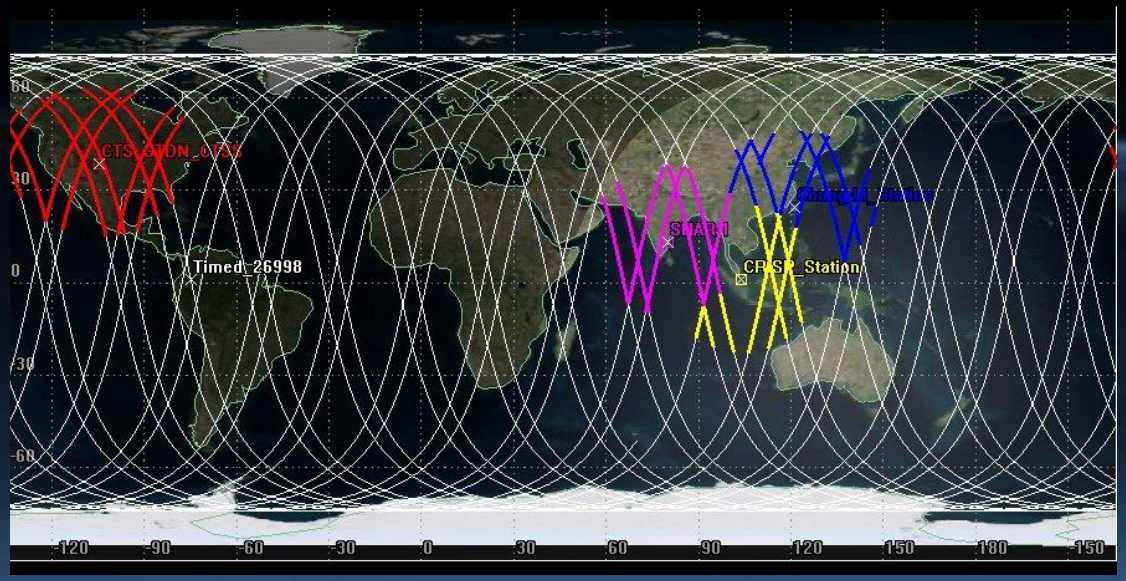


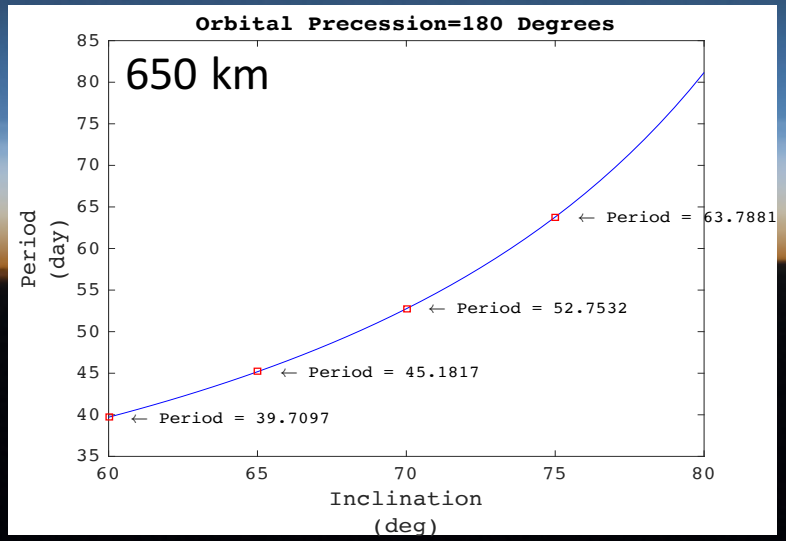





| | |
|---|---|
| **Mass** | 4 kg |
| **Volume** | 29 x 10 x 9 cm (3U) |
| **Power** | Standby and Operational: 7 W<br>Safehold: 1 W<br>Off: 0 W |
| **Pointing Knowledge** | ±0.5 arcmin, all axes |
| **Pointing Stability** | < 6 arcsec/sec |
| **Attitude Control** | 1° all axes |
| **Field of View** | Sun most not appear in field of view. |
| **Spacecraft Velocity Knowledge** | ±1 m/s |
| **Data Rate** | Downlink 200 Mbits/day |
| **Thermal Stability** | FPA: ±0.1 K/minute<br>Gas Cell: ±1 K/minute |
| **Thermal Requirement** | Anti-Sunward Side: -10 – 0°C<br>Ricor K527 Cryocooler |
| **Observed Emission** | NO 5.3 $\mu$m<br>Lockheed Martin SBF204 FPA |

# Mission Concept



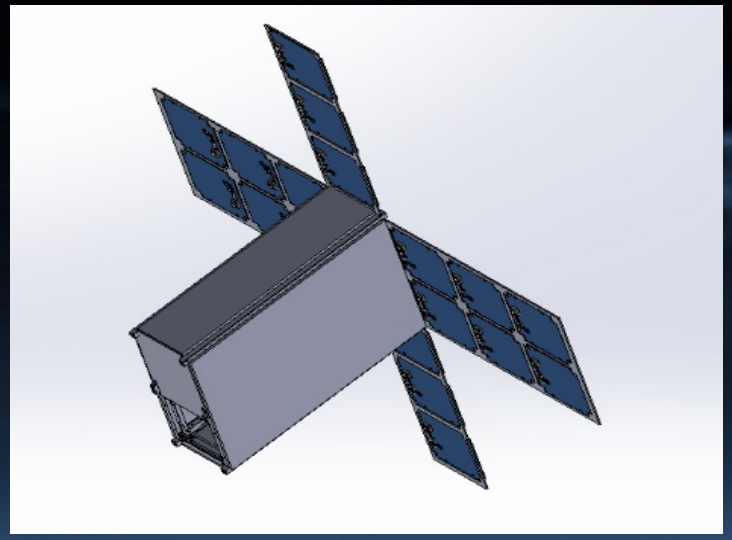

- 350 – 650 km circular orbit.
  - Estimated lifetime: > 1 year (350 km)
- Mission objectives:
  - Tech demo of DWTS wind and temperature measurements from 30 – 200 km.
  - Demonstrate using lunar scans to mitigate stray light effects.
  - Sample all local times for all longitudes from 60°S - 60°N latitude (3 month operational period).

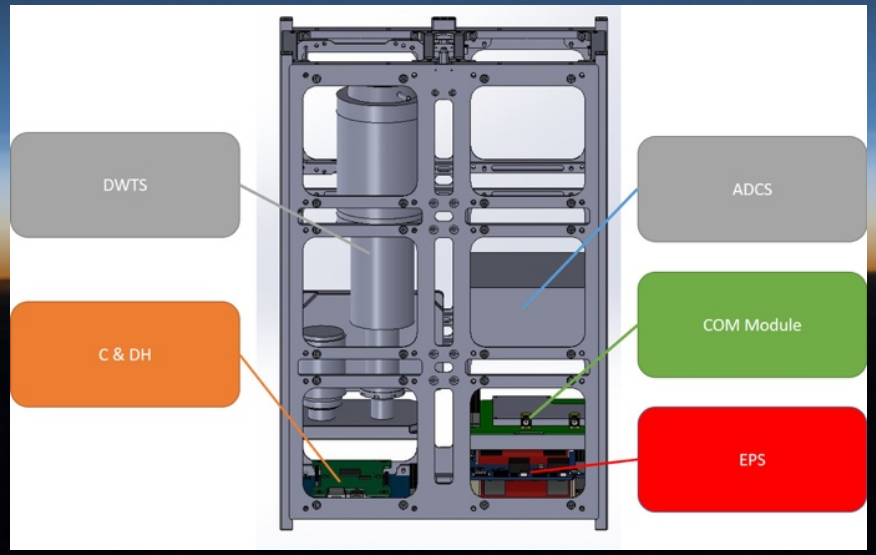
Is this feasible using a CubeSat platform?

# DWTS Requirements & Solutions

| | | |
|---|---|---|
| **Mass** | 4 kg | 6U CubeSat bus |
| **Volume** | 29 x 10 x 9 cm (3U) | |
| **Power** | Standby and Operational: 7 W<br>Safehold: 1 W<br>Off: 0 W | Multiple EPS module and battery options from Clyde Space, GOMSpace.<br><br>20 x GOMSpace NanoPower P110 Series solar panel |
| **Pointing Knowledge** | ±0.5 arcmin, all axes | Blue Canyon XACT ADCS<br><br>Periodic yaw maneuvers |
| **Pointing Stability** | < 6 arcsec/sec | |
| **Attitude Control** | 1° all axes | |
| **Field of View** | Sun most not appear in field of view. | |
| **Spacecraft Velocity Knowledge** | ±1 m/s | Multiple COTS GPS solutions:<br>SkyFox Labs pqNAV-L1/FM, Surrey SGR-05U, SSBV GPS Receiver, GPSRM 1 |
| **Data Rate** | Downlink 200 Mbits/day | Astrodev Helium (VHF/UHF)<br>Ground Stations:<br>Colorado, Taiwan, Singapore, India |
| **Thermal Stability** | FPA: ±0.1 K/minute<br>Gas Cell: ±1 K/minute | Integrated Ricor K527 Cryocooler (DWTS)<br>Passive thermal control components. |
| **Thermal Requirement** | Anti-Sunward Side: -10 – 0°C | |

# Power Budget using COTS Solutions

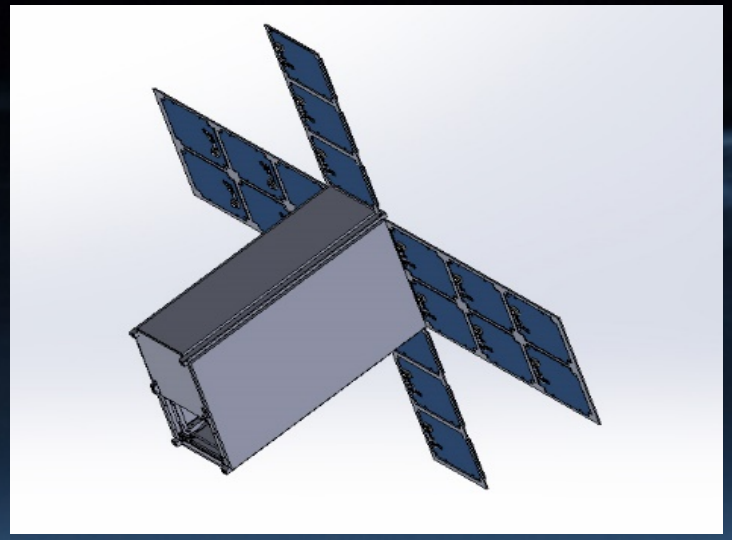


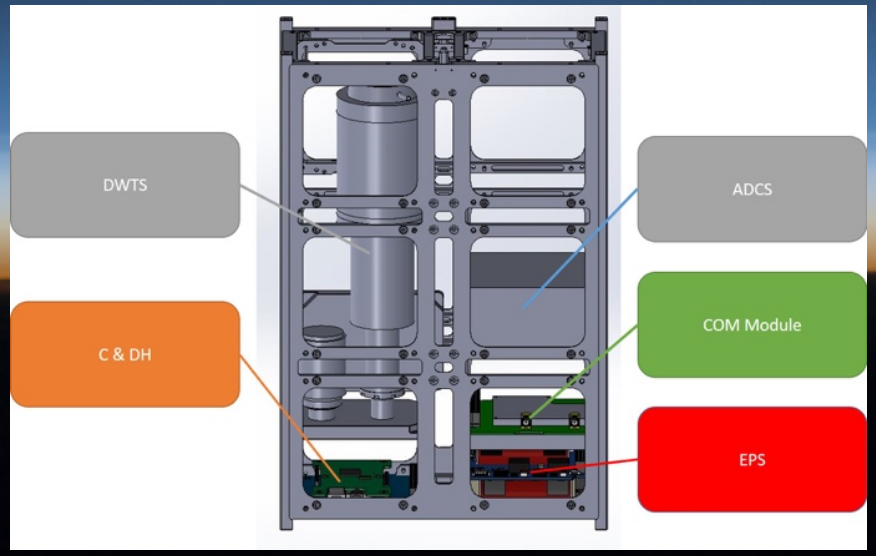



| INSPIRESat-1 Power Budget (Full Duty Cycle) | | |
|---|---|---|
| **Subsystem** | Power Requirement | Notes |
| **DWTS** | 7 W | Operational & Standby modes |
| **NAV** | 1.3 W | GPSRM |
| **EPS** | - | |
| **CDH** | 0.003 W | CubeSat Kit Motherboard |
| **COM** | 6 W | Astrodev Helium (Transmit mode) |
| **ADCS** | 2.83 W | Blue Canyon XACT |
| **Total** | **17.133 W** | |
| **Margin** | 0.8566 | 5% required power consumption. |

| | **Requirement** | **COTS Solution** |
|---|---|---|
| **Solar Panel Power** | **44 W** (30% power loss) | 20 x GOMSpace NanoPower P110 Series solar panels |
| **Battery Capacity** | **20 Wh** (70% efficiency, 80% DOD) | Multiple EPS module and battery options from Clyde Space, GOMSpace. |

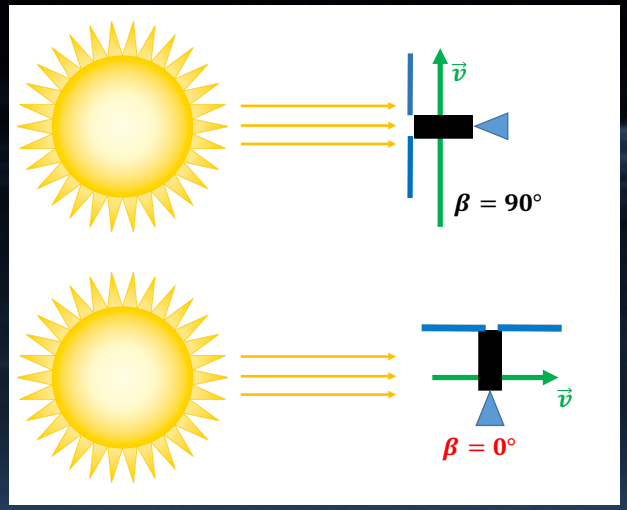
# Mass Budget using COTS Solutions






| INSPIRESat-1 Mass Budget | | |
|---|---|---|
| **Subsystem** | Mass | Notes |
| **DWTS** | 4 kg | - |
| **NAV** | 0.012 kg | pqNAV-L1/FM |
| **EPS** | 0.2 kg<br>0.6 kg | Power supply<br>GOMspace solar panels |
| **CDH** | 0.088 kg | CubeSat Kit Motherboard |
| **COM** | 0.078 kg | Astrodev Helium<br>(no antenna) |
| **ADCS** | 0.85 kg | XACT Capability |
| **STR** | 1.64 kg | Pumpkin SuperNova 6U |
| **TCS** | - | TBD |
| **Total Estimate** | **7.468 kg** | |
| **Margin** | 0.532 kg | Based on 8 kg total mass requirement. |

# Risks Identified




| | |
|---|---|
| **Pointing Knowledge** | ±0.5 arcmin, all axes |
| **Pointing Stability** | < 6 arcsec/sec |
| **Attitude Control** | 1° all axes |

| **Steady State Temperature Range (600 km): -69.4°C ~ 50.1°C** | |
|---|---|
| **Components** | Operational |
| **EPS** | -40 ~ 85°C |
| **Batteries** | 5 ~ 20°C |
| **Solar Panels** | -150 ~ 110°C |
| **DWTS** | -30 ~ 20°C |
| **GPS** | -40 ~ 85°C |
| **ADCS** | -10 ~ 40°C |
| **Motherboard** | -40 ~ 85°C |
| **Antennas** | -100 ~ 100°C |

| **Subsystem** | **EPS** | **ADCS** | **Thermal** |
|---|---|---|---|
| **Risk** | High power requirements<br>No Sun at certain beta angles | Attitude knowledge and control requirements | Expected temperature range exceeds component survival range. |
| **Mitigation Options** | • Reduced payload duty cycle<br>• Steerable solar panels<br>• Perpendicular fixed arrays | • Blue Canyon XACT ADCS module<br>• DWTS cryocooler duty cycling to minimize disturbance torques. | • Component level thermal modelling.<br>• Passive thermal control components for non-payload subsystems. |

# Summary & Future Work

- INSPIRESat-1 with DWTS as payload addresses pertinent scientific needs for middle and upper atmospheric wind and temperature measurements on a global scale.
- Independent preliminary studies from students at NCU, CU, and IIST show that a 6U CubeSat with COTS components is feasible as a spacecraft option for DWTS.
- Conceptual designs and analysis being used to modify payload design and mission success criteria, in preparation for payload and spacecraft fabrication.