Drag and Atmospheric Neutral Density Explorer (DANDE)

Hermes CubeSat

RocketSat

Testing Strategies for a Student Built Projects

Colorado Undergraduate Space Research Symposium

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The Hermes Mission

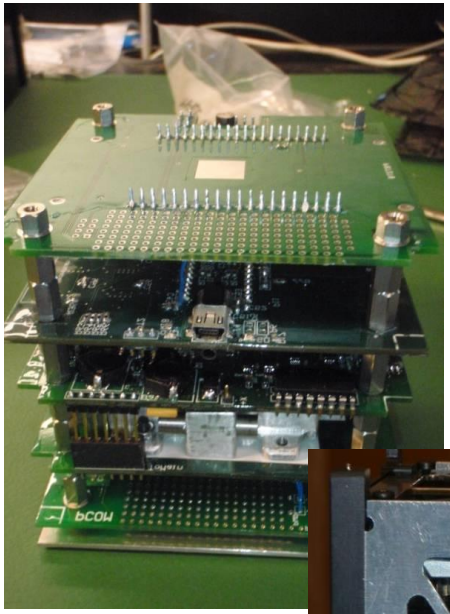
CubeSat Program

- Developed by CalPoly and Stanford Universities
- Over 60 universities, high schools, and private firms involved

- **Mission Statement**
  - *To provide practical reliable and cost-effective launch opportunities for small satellites and their payloads.*

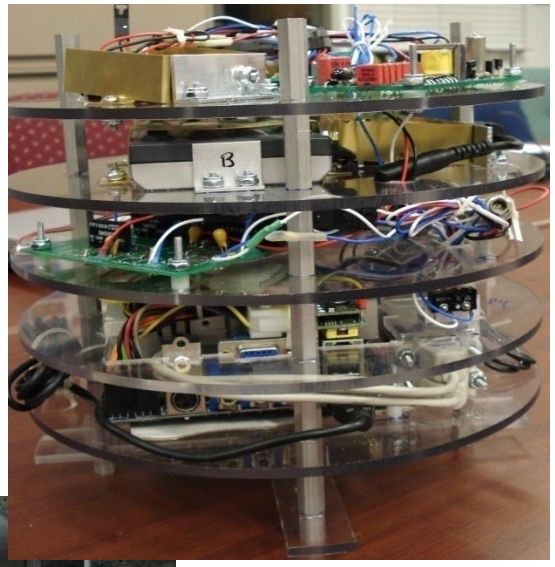
Hermes CubeSat: Mission

- **Primary Mission Goal**
  - *Create a generic bus for future use*
  - *Provide valuable knowledge and experience to undergraduate students*
- **Secondary Mission Goal**
  - *Demonstrate the use of S band communication system for higher data throughput*
  - *Gather environmental data*



The RocketSat Mission

RocketSat: Mission



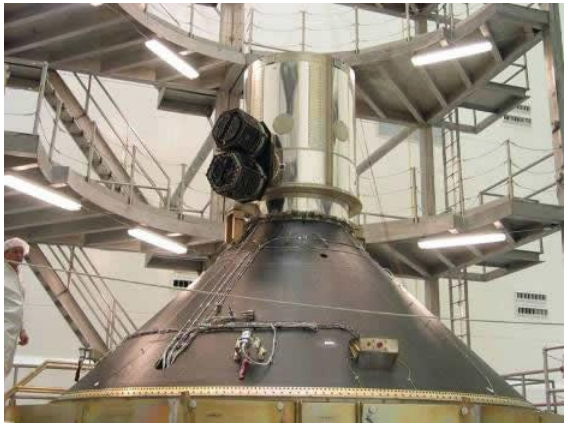
- **Program Goal**
  - *To provide hands-on, space based engineering experience to young engineering students*

- **RS VI Goal**
  - *Measure large aerosol particle density and charge from 75 to 95 km to characterize the numerical density distribution of these particles and the charge of the particles in this region of the atmosphere*

The DANDE Mission

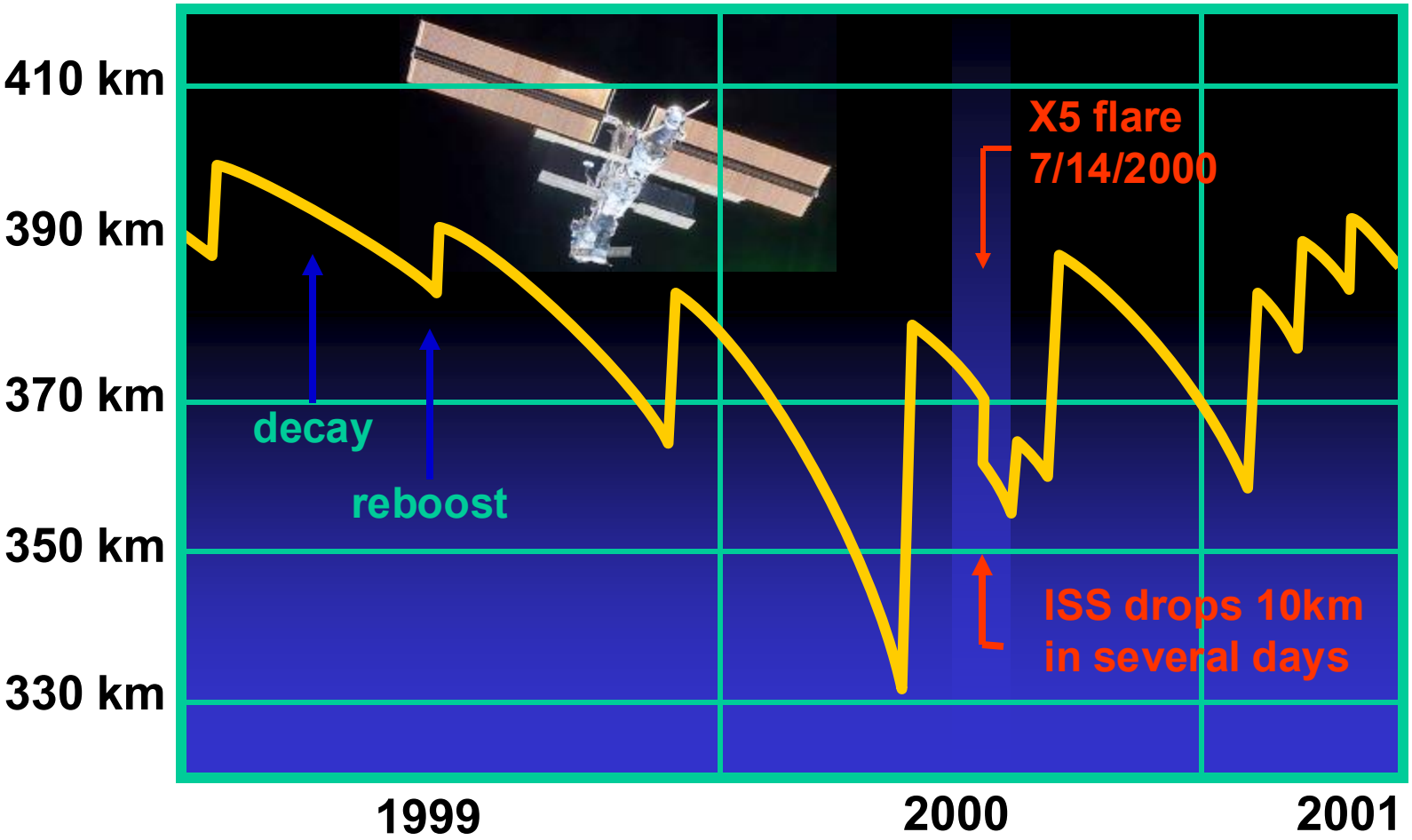
The University Nanosat Program

- *University Nanosat – The National Championships of Spacecraft Design*
  - **2 year program** *now in its sixth iteration*
  - *Competition to build satellites*
  - *10 out of 30 university proposals selected based on* **Air Force Relevance**
  - *UN5 WINNER:* **January 2009**,
    - *Flight to Orbit*
    - *Additional funding*
    - *I&T at Kirtland AFB*
- *CU Nanosat Entry*
  - *Has involved a core team of more than 60 graduate and undergraduate students*
- *SERB*
  - *Received ranking!*



Operational Importance of Drag

The density of the atmosphere in this region **varies greatly** (300% to 800%*) due to space weather and not yet understood coupled processes.



E. Semones et.al. WRMISS 10
http://www.oma.be/WRMISS/workshops/tenth/pdf/ex02_semones.pdf

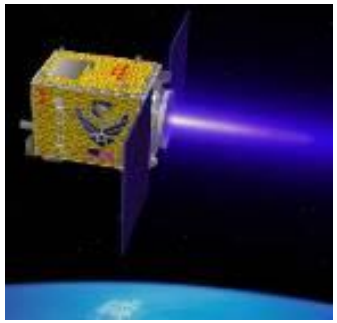
** Forbes et. Al. "Thermosphere density response to the 20-21 November 2003 solar and geomagnetic storm from CHAMP and GRACE accelerometer data", Journal of Geophysical Research, Vol. 111, June 2006*

DANDE Analogy

:

as

DANDE :



The DoD has been interested in neutral density since it has been interested in spacecraft
Important to:

- •tracking (NORAD)
- •re-entry
- •formation flying and rendezvous
- •Orbit prediction

Mission Overview

- **Mission Statement**

  Explore the spatial and temporal variability of the neutral thermosphere at altitudes of 220-62 miles (350 -100 km), and investigate how wind and density variability translate to drag forces on satellites.

- **Mission Objectives**
  - *Understand the relationship between total mass density, composition, and winds as functions of latitude, level of magnetic activity, and horizontal scale.*
  - *Study how density and winds affect satellite drag as a function of latitude, magnetic activity, and horizontal scale.*
  - *Improve understanding of the variation in coefficient of drag in the 62-125 miles (100-200 km) altitude region.*
- **Technology Demonstration**
  - *Spacecraft bus to perform low-cost in-situ measurements of the drag environment*
  - *Low cost acceleration measurement system*
  - *Miniaturized wind sensor and spectrometer*
  - *Starsys separation mechanisms*

Testing Strategies for a Student Built Projects

Test Plan Purpose

- *Why is a test **plan** needed?*

- *What does a plan do?*

- *How is one organized?*

Test Plan Purpose – Organization

DANDE

COM701 Anechoic Chamber Test Plan

STR701.1 Engineering Unit Vibe Test

EPS702.1 Voltage and Current Loading Test Functional Test

SEP702.0 **TVAC Separation**

EPS703.1 Voltage and Current Sensor Calibration

NMS701.0 NMS Electronic Functional

EPS703.0 Voltage and Current Sensor Calibration

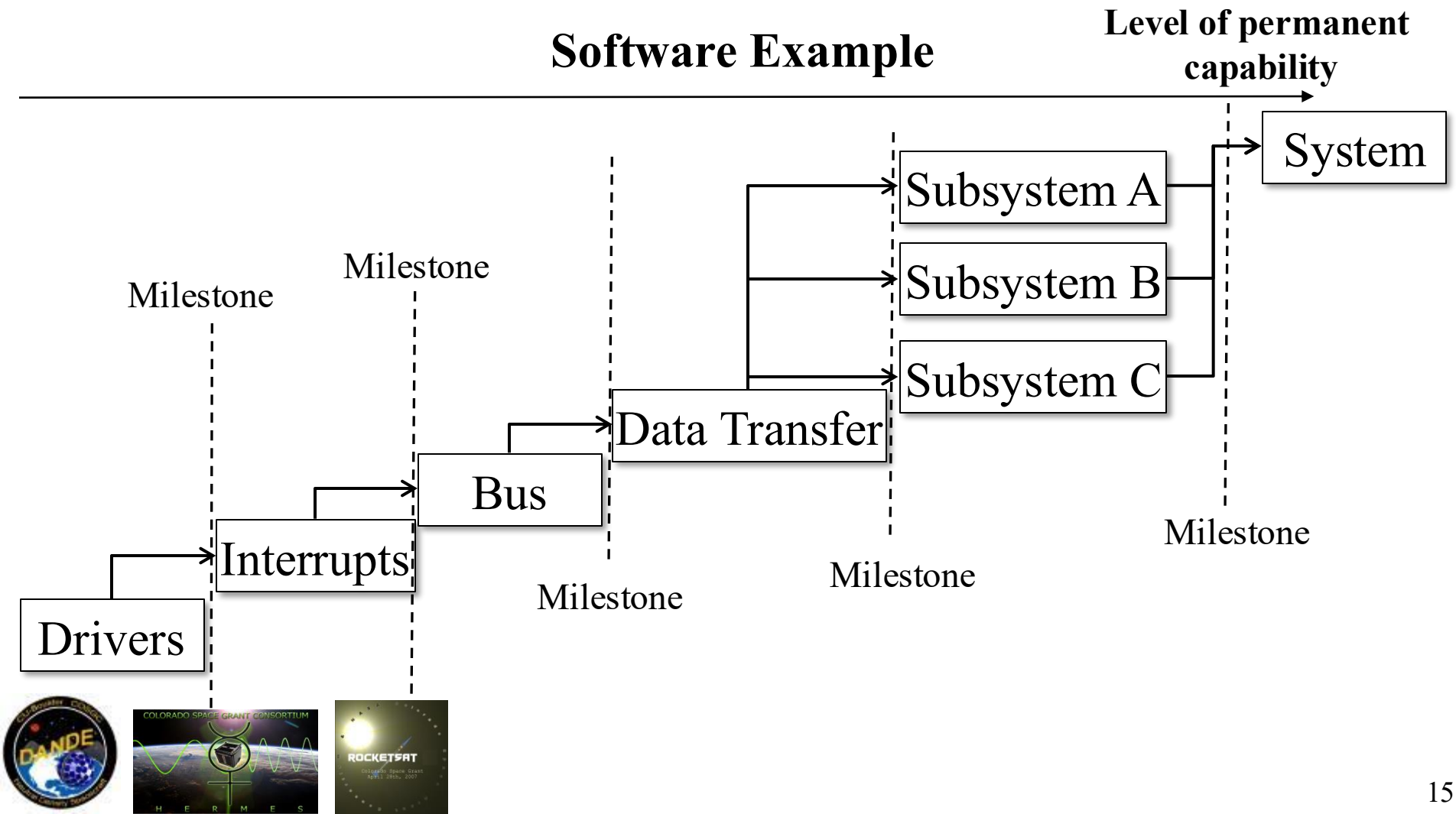
SYS703.0 **Authority Spin Test**

NMS702.0 Preliminary Vacuum Test

- *Hermes and RocketSat*
  - *Frequently Informal*
  - *Subsystem lead check-off*
  - *Documentation not as heavily required by these programs*

Test Plan Purpose – What does it do?

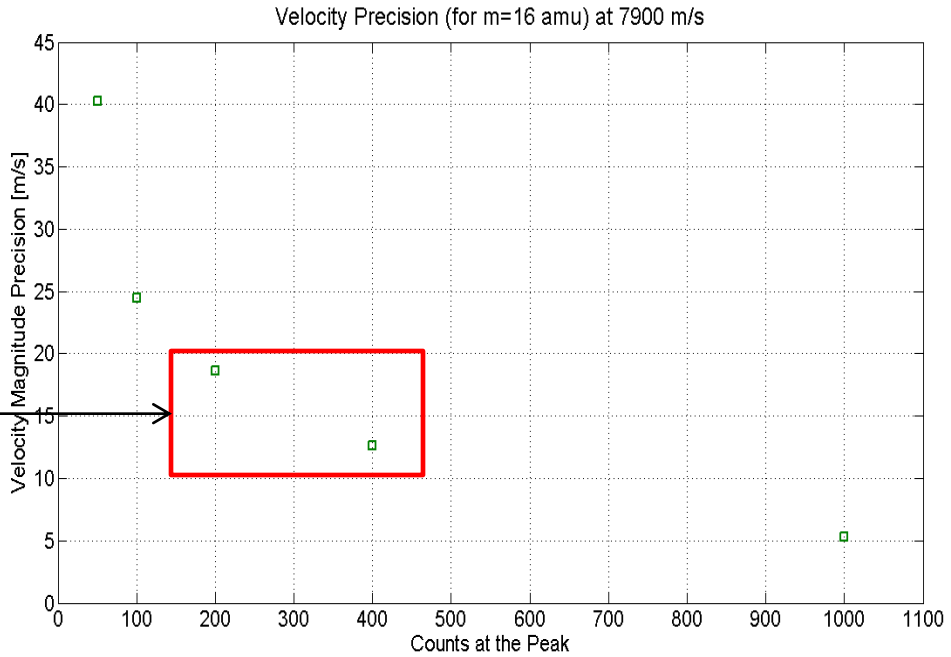
Key point to testing: understand what the system can do while achieving a new level of capability on the system



Test Plan Purpose - Requirements

- *In the end, requirements dictate what should be tested and how well a design should perform during that test*

'The NMS shall measure wind magnitude with a 1-sigma precision of ± 100m/s. GOAL: NMS should measure the wind magnitude to within 20 m/s.'



Testing Philosophy

When to test:

a) *Advisor input*

b) *Avoid 'Paralysis by analysis'*
   - *Calibrations*
   - *Difficult and un-modelable behavior: (damping, frequency response, mechanism behavior…)*

c) *Verify requirements*

d) *Demonstrate capability of design through a milestone*

The projects have found that using new team members when possible on tests to get them integrated and excited about hands-on work!

Testing Philosophy

How often to test:

Electronics

As early and often as possible!

- *Hermes: ~ 5 CDH iterations*
- *DANDE: 3-6 iterations, depending upon subsystem*
- *RocketSat: 5 iterations*

A FLATSAT IS A WONDERFUL THING

Mechanical

Engineering unit and flight unit builds are incredibly important!

- *Too much cycling can cause fatigue*

The structure is often sufficient or over designed. Testing is necessary but getting good data is often difficult

Transport and shipping equipment are often overlooked but very important to ensure system reaches 'launch' zone safely!

- *Load testing and fit checks a must!*

External vs. Internal Testing

External testing: ONLY when a resource is inaccessible to the project

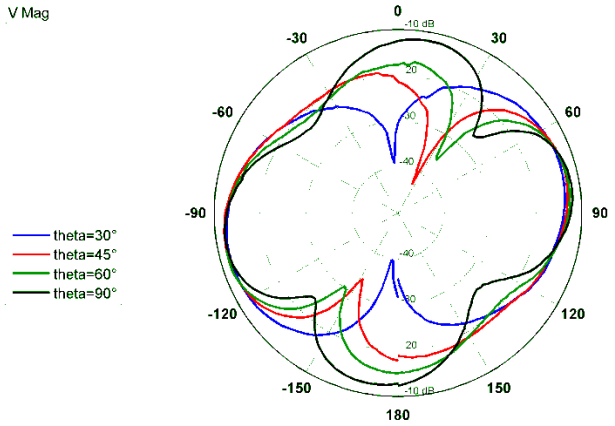
Cons:

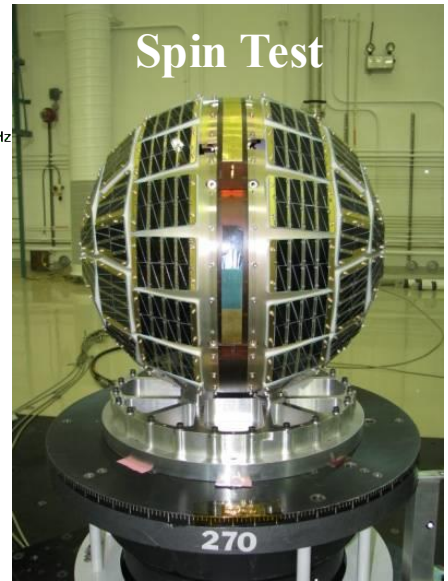
- *Difficult to acquire facilities*
- *Time consuming preparation*
- *Risky for components during travel, apparatusing and other difficulties associated with external tests*
- *Often requires team to create apparatuses and fixtures*
- *Cannot test on the team's schedule causing stress and long hours*

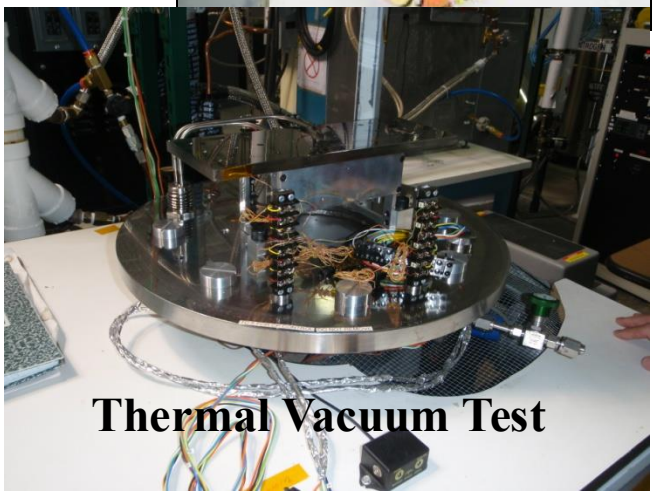
Pros:

- *Provides information unattainable otherwise!*

External vs. Internal Testing







External vs. Internal Testing

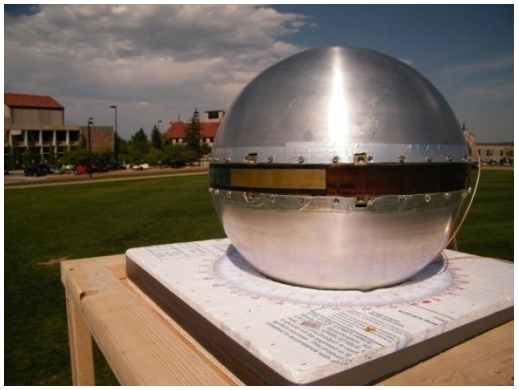
Internal testing: the majority of tests

Cons:

- *May have lower fidelity results*

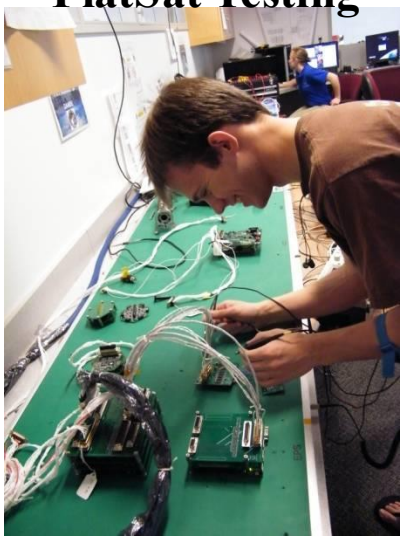
Pros:

- *Testing can occur on the team's schedule*
- *Testing can occur often and multiple data points can be created*
- *Most testing does not need specialty equipment*



DANDE COM Field Testing

FlatSat Testing



Hermes COM Field Testing

Industry

- *Industry engineers can provide:*
  - *Advise*
  - *Years of experience and knowledge*
  - *Test facilities*
- *Building and keeping a good relationship with industry engineers has helped to advance all the projects*
  - *RocketSat has had several industry and lab based customers*
  - *CubeSat and DANDE have received advising, testing*

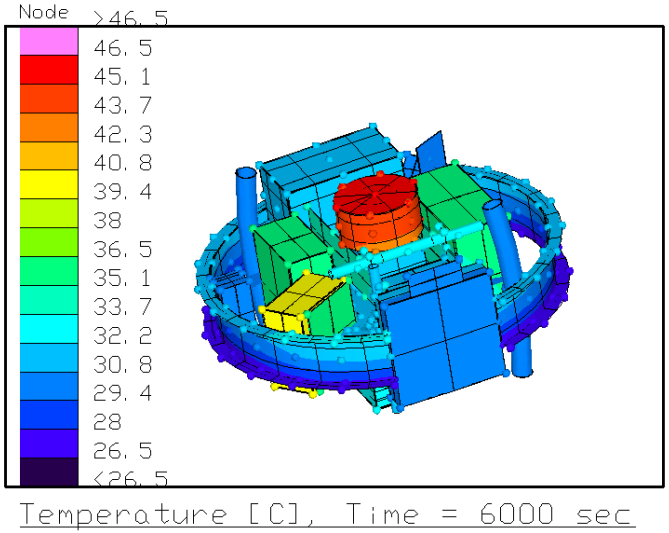
DANDE at FirstRF

It has been fun for students and Professionals alike!

Hermes Discussion Vibe Testing at Ball

When Not to Test

- *Analysis can be faster and cheaper!*
  - *Industry uses models a lot for a reason*
- *Be wary of destructive testing*
  - *Often times, this does not produce that great of results, just yes/no answers*
- *Apparatusing and tests take thought and design as well*

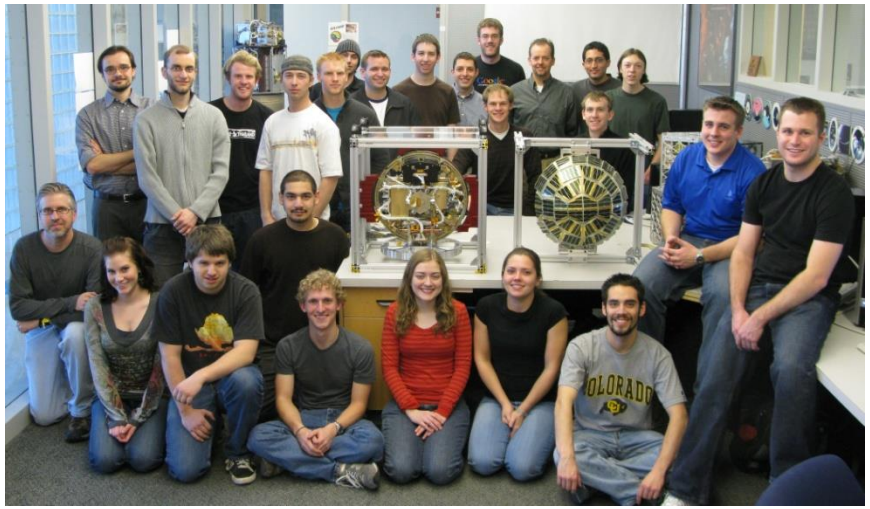


DANDE Thermal Model

Test Plan Purpose - Conclusions

- *Why is a test **plan** needed?*
  - *Start with the end in mind*
  - *If you cannot test it, how will you know it works?*
  - *Know what time crunches will be waiting at the end*
  - *Make achievable milestones for engineers*
    - *Holds engineers accountable for progress*
    - *Allows them to demonstrate their hard work frequently*
- *What does a plan do?*
  - *Identify how requirements are verified and verifies them*
  - *Validates assumptions*
- *How is one organized?*
  - *Depends upon team*
  - *Use of test procedures, scheduling*

QUESTIONS?



DANDE team Jan 2009

Hermes team Aug 2009

RocketSat VI team

Backup Slides

Testing


Anechoic Chamber


Actuator Testing

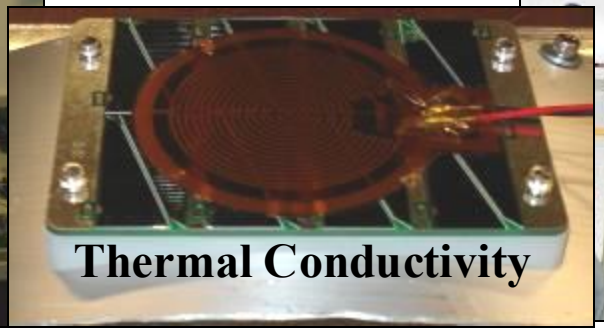

Instrument Calibration


Vibration Test

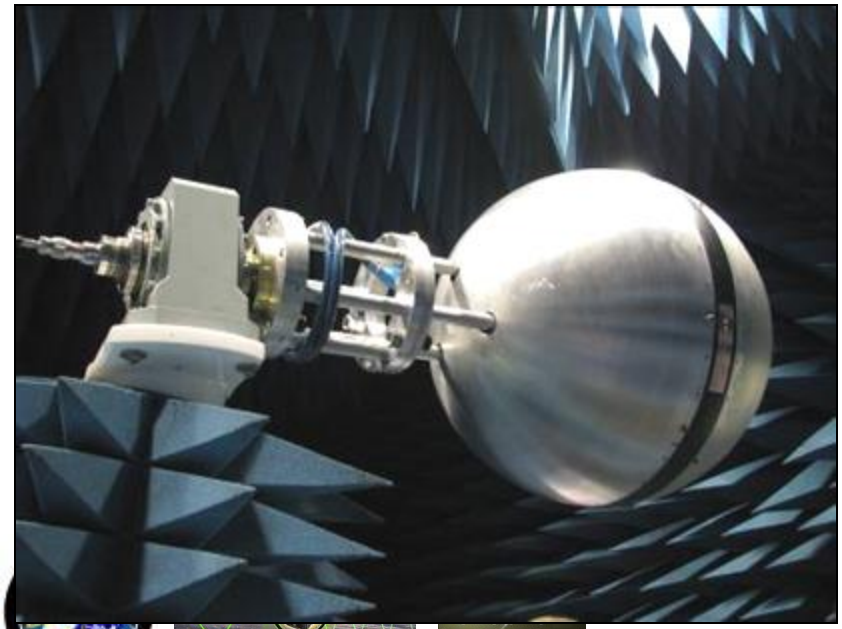

Solar Cell Trade Study


Mechanism Tests

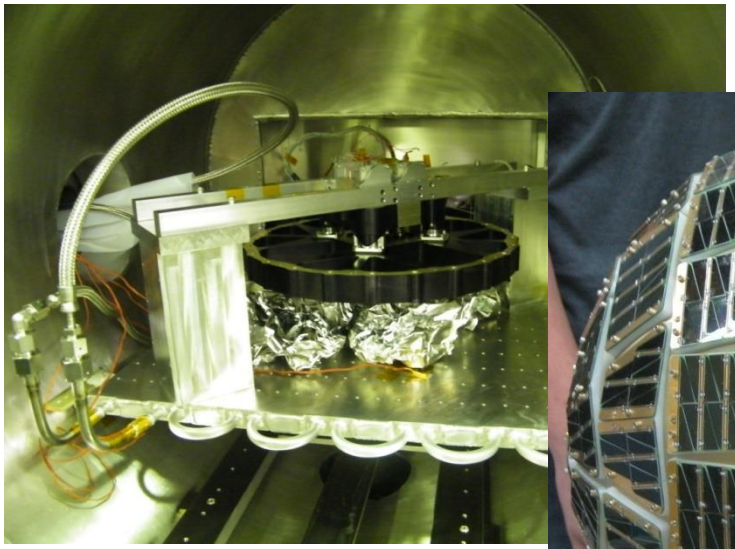

Electronics and Software

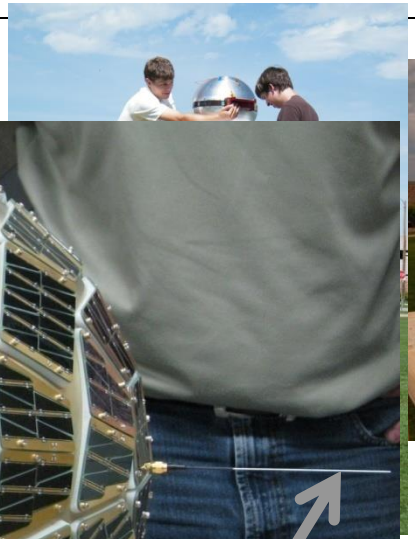

Thermal Conductivity

Testing 2007-2008



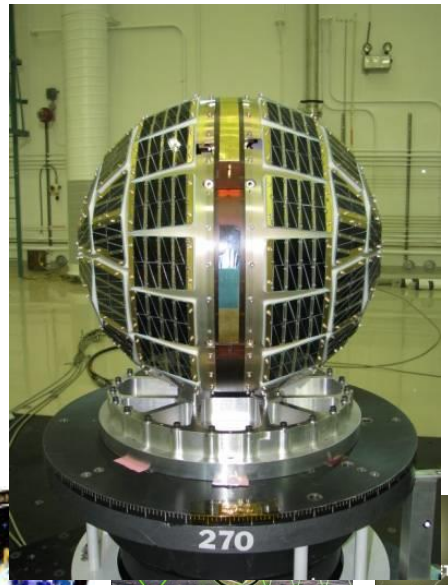
Testing 2009-2010

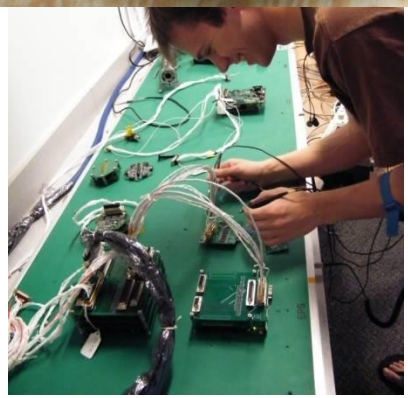


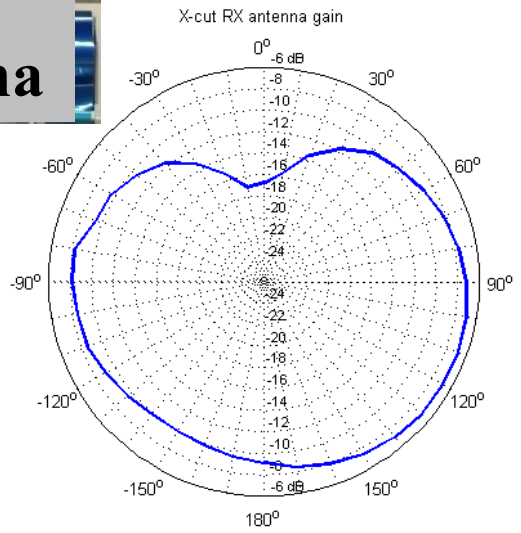


COM

Whip Antenna

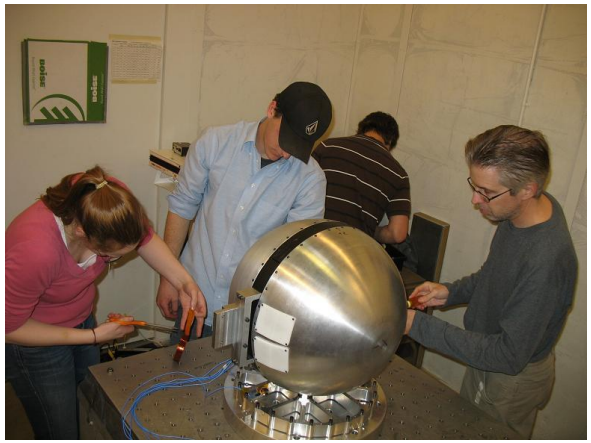


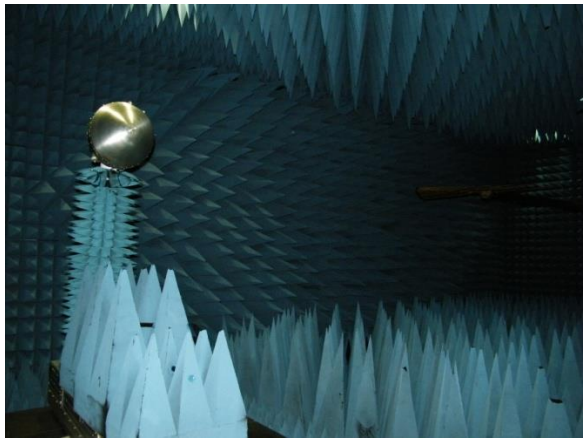


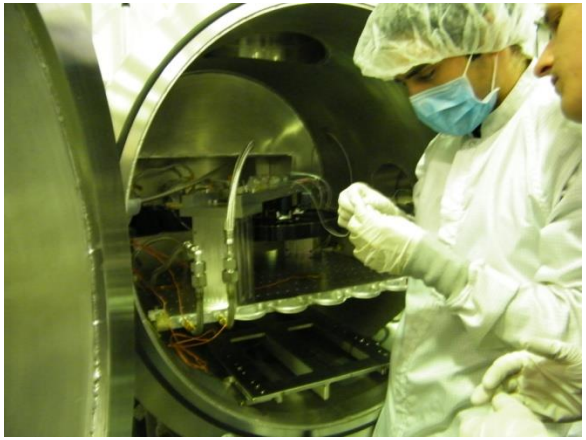


Post-Delivery Testing

- *AFRL Testing*
  - *Spin/Mass properties*
  - *EMC/EMI*
  - *TVAC*
  - *Vibration/Shock*

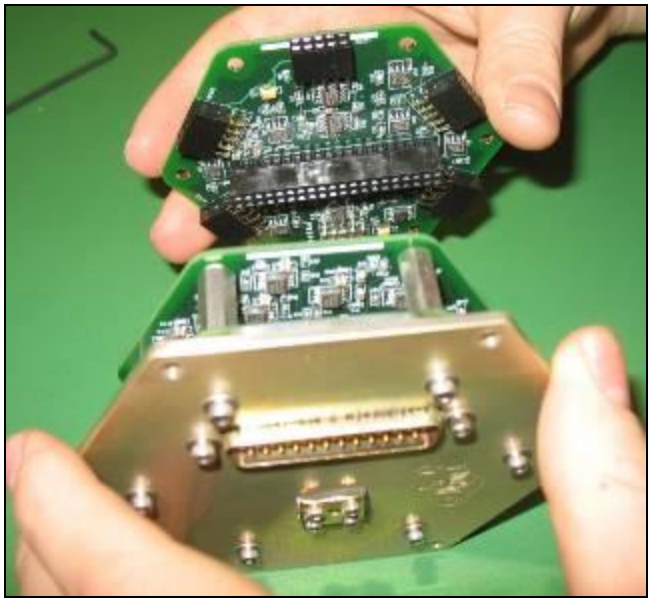


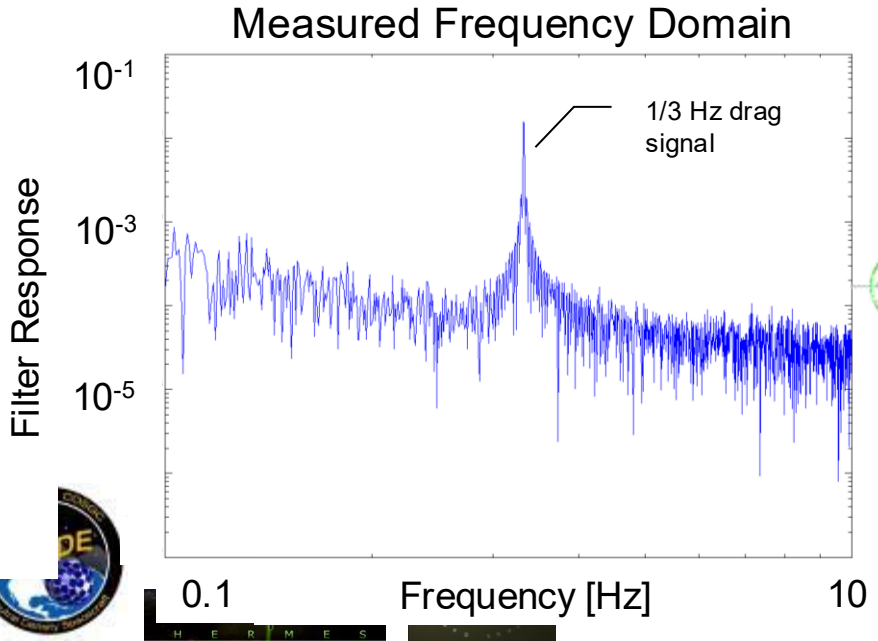


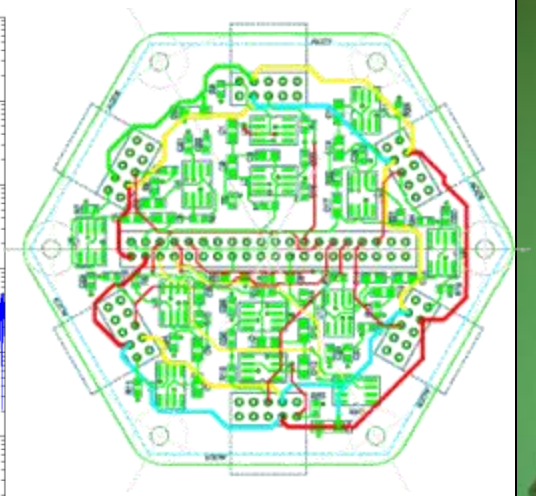


Technology Development: Accelerometers

- *Measures accelerations with sub-μg precision*
- *Status: Calibration Testing through June 2009*
- *TRL 1 → TRL 6*
- *End goal – low cost drag monitoring method*

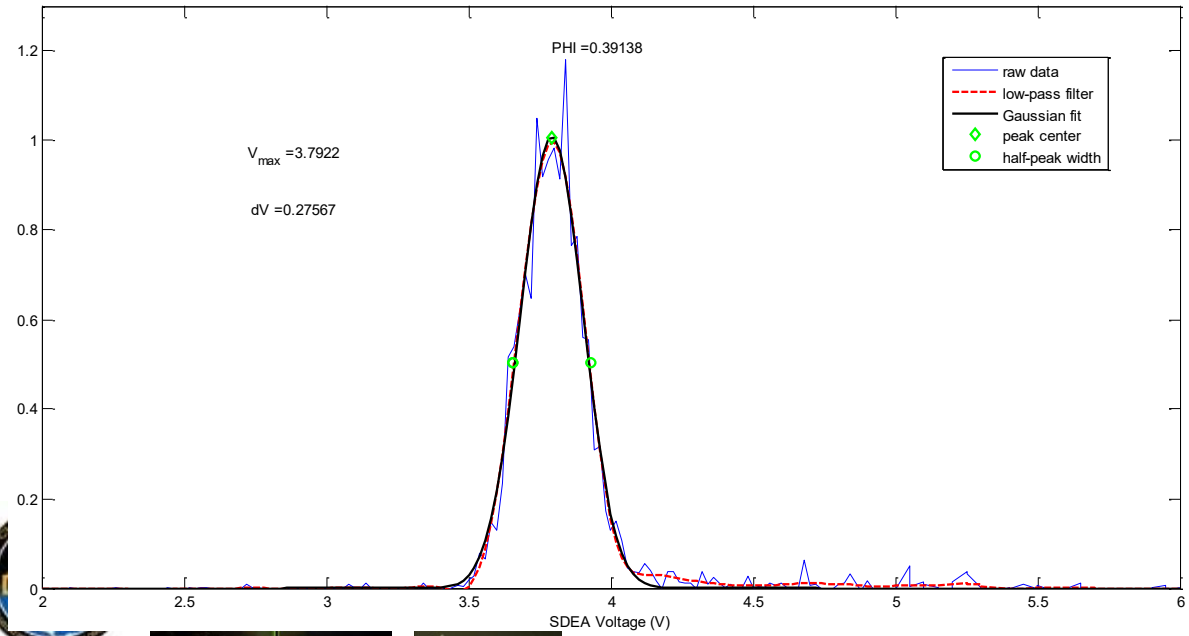




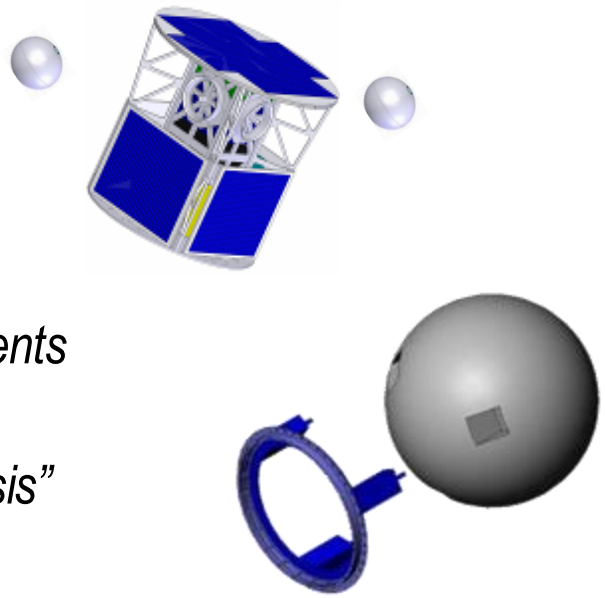


Technology Development: Mass Spectrometer

- *Measures Wind, Composition, and Temperatur*
- *Preliminary Testing Complete*
- *Status: Calibration testing planned end of May*
- *TRL 3 → TRL 6*
- *Important addition to observing the atmosphere*
  - *Applies to future SWARM missions and DSMP*



Lessons Learned



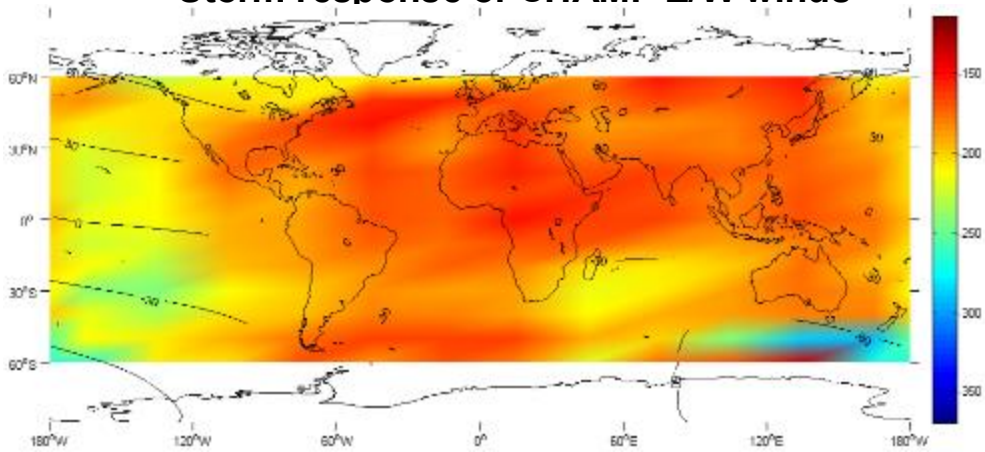
- *Having the right mission*
- *Choosing the right scope*
  - *Identify the "tall poles": cost/difficulty*
  - *can we do 90% of the mission with half the cost and risk?*
- **REQUIREMENTS**: *Take your time and do the requirements correctly.*
- *Refine the analysis but be careful of "paralysis by analysis"*
- **KEEP IT SIMPLE:** *BETTER IS THE ENEMY OF GOOD*
- **PLAN FOR ITERATIONS**
- **TESTING, TESTING, TESTING**
- *The biological subsystem, the most important part of the program*
  - *Respect class schedules and schoolwork.*
  - *Align research with the program where possible*
  - *Work around advisors schedules and don't be afraid to ask for help*

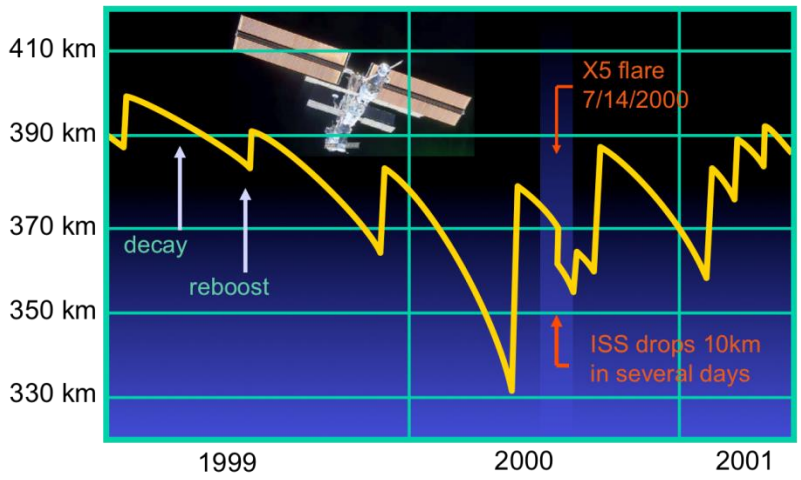
Mission Motivation: Prediction Capability Development

Improved Thermospheric Model and First-Ever Measurements

- *Better Prediction and Near Real Time Observations*
- *Low cost to deploy*
- *Validation and improvement of models*
  - *HWM (NRL)*
  - *TIME-GCM (NOAA)*
  - *HASDM (AFRL/A9A)*
- *Improved drag coefficient modeling*
- *End goal – transfer to small satellite community interested in precise orbit operations in LEO*

Storm response of CHAMP E/W winds





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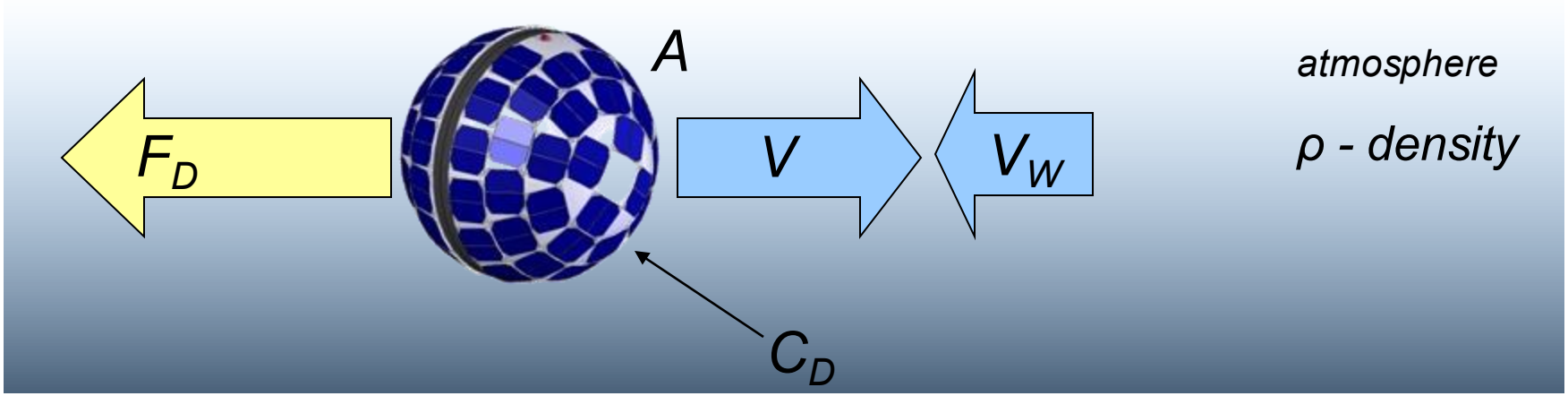
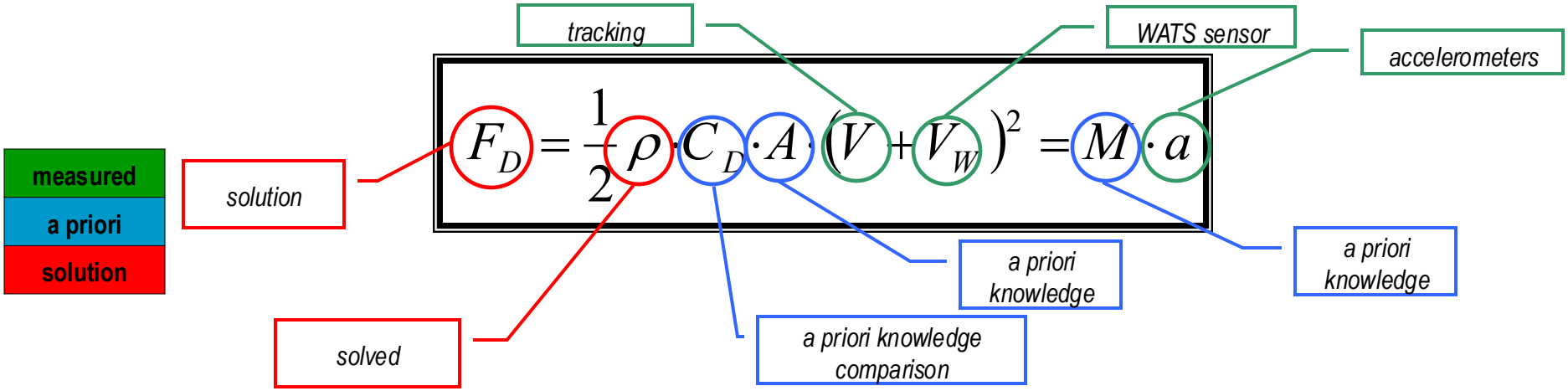
How Measurements are Made





- *Identifying all components of the constituents of the drag equation.*
- *With a near-spherical shape, an a-priori physical drag coefficient may be calculated and a physical density can be obtained from the measurements*