Designing Satellites for Effective Mission Operations

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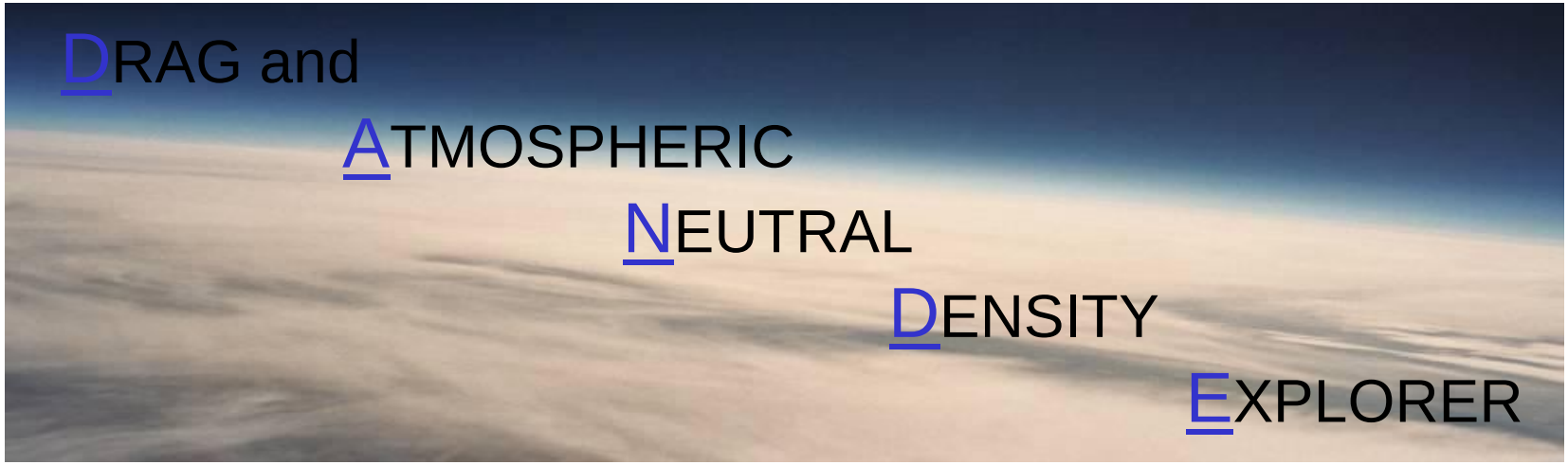
Agenda

- Mission Overview
- Communications
- Beacon
- Commanding
- Mission Operations
- Ground Station
- ADC
- Questions

Before Launch

- DANDE development started in 2007
- MOPS was started in Fall 2011
- MOPS team learned how to operate satellite.
- MOPS team was not as involved in designing the satellite.

Purpose of DANDE



Mission Statement

Explore the spatial and temporal variability of the neutral thermosphere at altitudes of 325- 400 km, and investigate how wind and density variability translate to drag forces on satellites.

DANDE Mission Overview

Launch
9/29/13

1/9/14 2/7/14

Activation | Magnetometer | Torque Rods | Loss of Contact | Loss of Cont.

9/29/13 Today

Separation
10/30/13

Contact
2/7/14

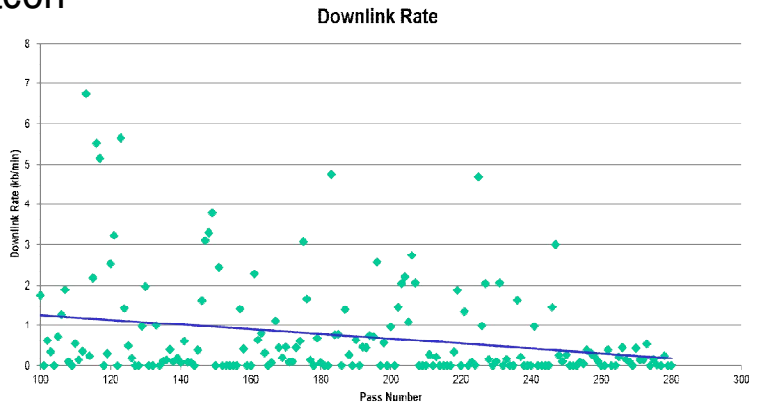
Lessons Learned Focus

Design satellites for the use cases of the mission operator.

Ensure testing reflects space operating conditions.

Communications

- Unstable link complicated concept of operations
  - Expected: 450 Bytes Per Second
  - Actual: 11.9 Bytes Per Second
  - Made objectives hard to convey
- Testing of the system should always be conducted in the same way as flight.
  - Using communication link and not direct lines with appropriate losses
- Including useful information about COM in the beacon
  - Ability to obtain quick status of system



Communications Continued…

- Orientation was very important to operations
- Complicated mission operations
  - Objectives could not be accomplished as scheduled
  - Required new methods of pass management
    - Pass Objectives document
  - New methods of Data Downlink
  - Utilization of the Post Pass Script

Vignesh Muralidharan

BEACON AND COMMANDING

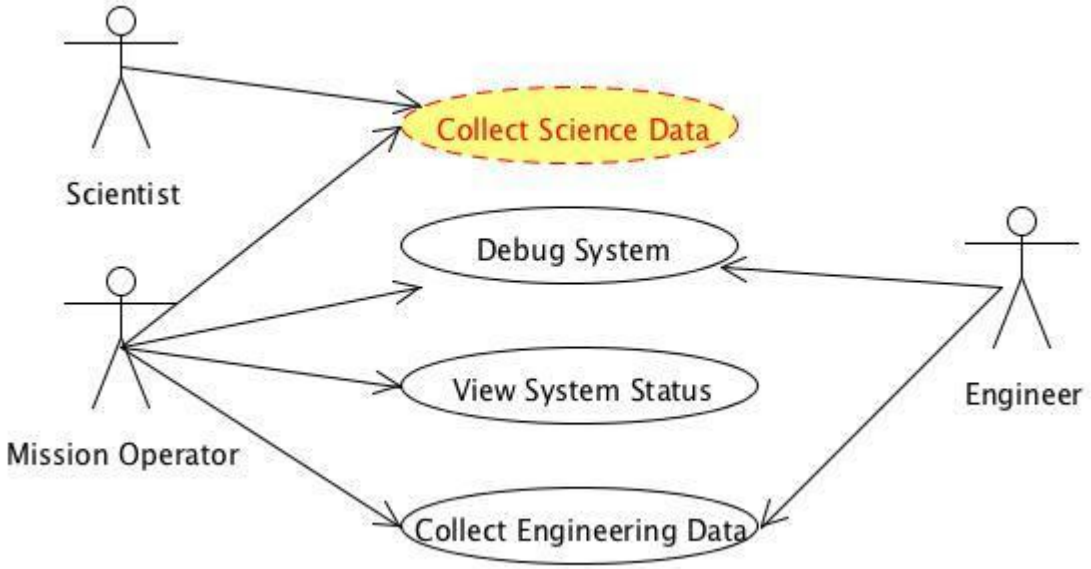
Beacon Data Products

- 3155 beacons collected from DANDE.
- 357,000 bytes collected from DANDE Beacons
  - Total data collected was 1.5 million bytes
  - 24% of total data collected from satellite.
- Beacons were collected from all over the world (minimum data collection).

Problems with DANDE Beacons

- 19 bytes of the beacon were EPS Data
  - MOPS team needed 3 specific bytes
    - Battery Charge %, PV Power Out, PV power in
    - Only PV power in was included in the beacon
    - Battery Charge % was critical
- Beacon contained information about whether CDH, COM_CDH, and COM were powered.

Example: Beacon Use Cases



Break Use Cases Down

Use Case: Collect Engineering Data

- Need to understand when subsystems can be turned on.
  - Requires battery state of charge.
- Understand which systems have critical data points.
  - DANDE ACC needs a spin rate of 9-11 RPM for succesful data collection.
  - Spin Rate in beacon would simplify ACC operations.

Use Case: Debug System:

- Characterize processor performance:
  - Load Average & Files on Satellite

Opportunities From Use Cases

- Use case design can provide motivation to collect difficult data products.
- Science Datacollection.
  - 20% to 30% of beacon (estimate by team) provided data products that were not useful.
  - Opportunity for additional 100,000 bytes of data.
  - Additional 20% of data over mission life time.

Commanding

- Difficult to determine where an error has occurred on DANDE
  - Need to sort through large error logs file.
  - Operator not aware of file structure on satellite.
  - Not discovered in testing due to to inaccurate testing settup.

- Ground Commands weren't tested in space operating conditions.
  - Command performance was vetted with a few hundred to a few thousand files on the satellite.
  - Actual satellite operated with 20,000 to 30,000 files.
  - Caused performance requirements of commands to not be met.

Franklin Hinckley

MOPS AND GROUND STATION

MOPS

- Procedures for unforeseen errors
  - Useful data to collect
  - Possible Interpretations
  - Fixes
- Clear communication of objectives
  - All team members understand current tasks
- Strict oversight of commanding
  - Prevent errors caused by simple mistakes
- Potential fixes ready
  - A potentially fatal scenario should have a fix prepared

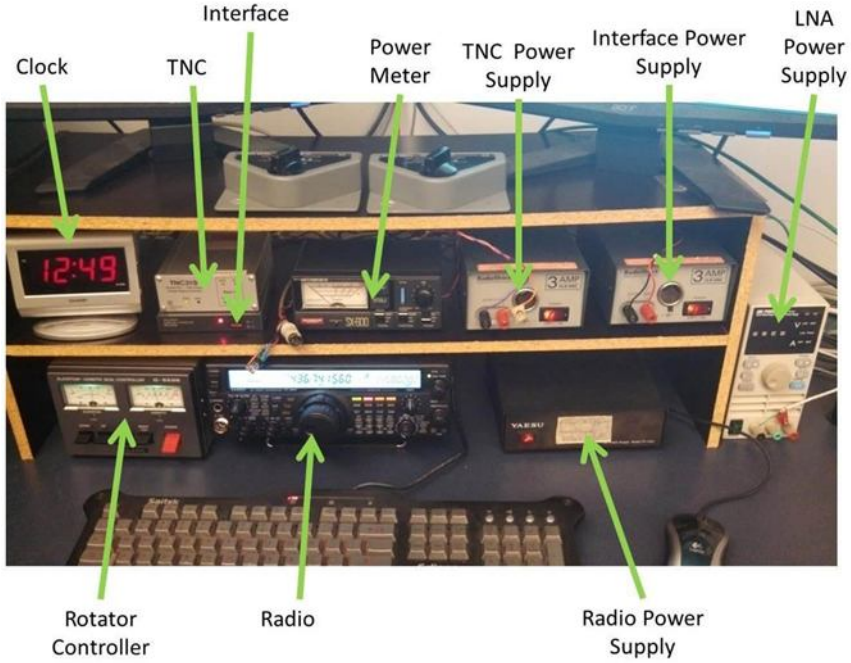
Autonomous MOPS

- Safe Mode should not be standby mode
- Satellite should be able to survive indefinitely during this time
  - Wide range of cases handled
  - Minimal system functionality
  - Prevents exacerbating errors
    - No data generation
  - Can recover independently from some errors
- Resets work as intended

0 - Safe Mode
1 - Fire Hop 1
2 - Fire Hop 2
3 - Standby
4 - Spin Up
5 - Adjustment
6 - MCP Ramp
7 - Filament Burn In
8 - Science
9 - Reduced Science

Ground Station for MOPS

- Simplicity
  - System is clear and friendly
- Debugging
  - Operators understand rationale
- Resilient
  - Common errors are not dangerous to system



Tanya Hardon

ATTITUDE PHASE

Attitude Phase

- Initial plan for attitude changed due to longer mission lifetime than initially anticipated
  - Scope of instrument verification greatly increased
- Didn't realize new plan was unreasonable/unnecessary until we started to analyze data
- Months of mission went into excessive data analysis

Attitude Phase - Success Criteria

Initial Criteria

- DANDE must be aligned within 2 DEGREES of cross-track direction
- Scribe files 1, 2 and 3 show a spin rate between 9 and 11 RPM
- Torque rods have fired as indicated by voltage changes in EPS Logfiles
- Successful mode change from: 3 -> 4 -> 3 -> 5 -> 4D -> 3

Adjusted Criteria

- Successful Mode change 3 -> 4
- Functional magnetometer
- Use Magnetometer data to determine pre-spin-up spin rate
- Functional Y Torque Rod
- Functional X Torque Rod
- Damping is Functional
- ADCM correctly calculates spin rate
- Nominal ADCM spins spacecraft faster about Y axis
- Nominal ADCM damps spacecraft motion about X and Z axes
- There are no critical system errors
- SOC > 80%

Conclusion

- Unfortunately we could not discuss the many successes of the DANDE mission due to the scope of this presentation.
  - DANDE achieved Level 1 Mission Success
- Including the mission operators in the design phase can result in a more effective system
- Testing for the space environment is key in verifying the functionality of the satellite

Questions?