Adapting a sophisticated Ground Data System for use by a Deep Space Cubesat Mission

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Overview

- Every mission must perform Mission Control functions through its development, integration, and operations lifecycle
  - Finding cost effective software can be a challenge for severely cost-constrained small missions
  - Cubesats do not typically need to interface with the NASA Deep Space Network
- INSPIRE chose the Advanced MultiMission Operations System (AMMOS) application AMPCS for Mission Control
  - Currently used on missions significantly more complex (and expensive) than a cubesat
  - Flexible, adaptable, and typically customized for unique mission requirements
  - Designed to operate across mission phases and environments, from initial development to operations
  - Designed to scale from a single workstation environment to a high performance, multi-node server environment

INSPIRE: Interplanetary NanoSpacecraft Pathfinder In Relevant Environment
AMPCS: AMMOS Mission Data Processing and Control System

Objectives

- This briefing describes how this Ground Segment software was adapted and used for flight software development, system integration and test, and DSN compatibility testing
- Lessons learned are presented, both for the adaptation process and for working with a small and agile spacecraft development team

Typical AMPCS-supported Mission: SMAP

- Large, complex, multi-year development
- GDS responds to the needs of flight software
  - Many custom features added to AMPCS during Mission Phase C/D
- Multiple test / verification environments and activities before being connected to the hardware

Image URL: http://www.nasa.gov/jpl/smap/2014-4268/#.VMrMmkhD9pZ

SMAP: Soil Moisture Active / Passive
GDS: Ground Data System

INSPIRE Mission Background

- Deep space cubesat pair
- Tech demo and characterization
- Embraced TAYF to reduce risk to operations
- Tiny team, everyone does everything

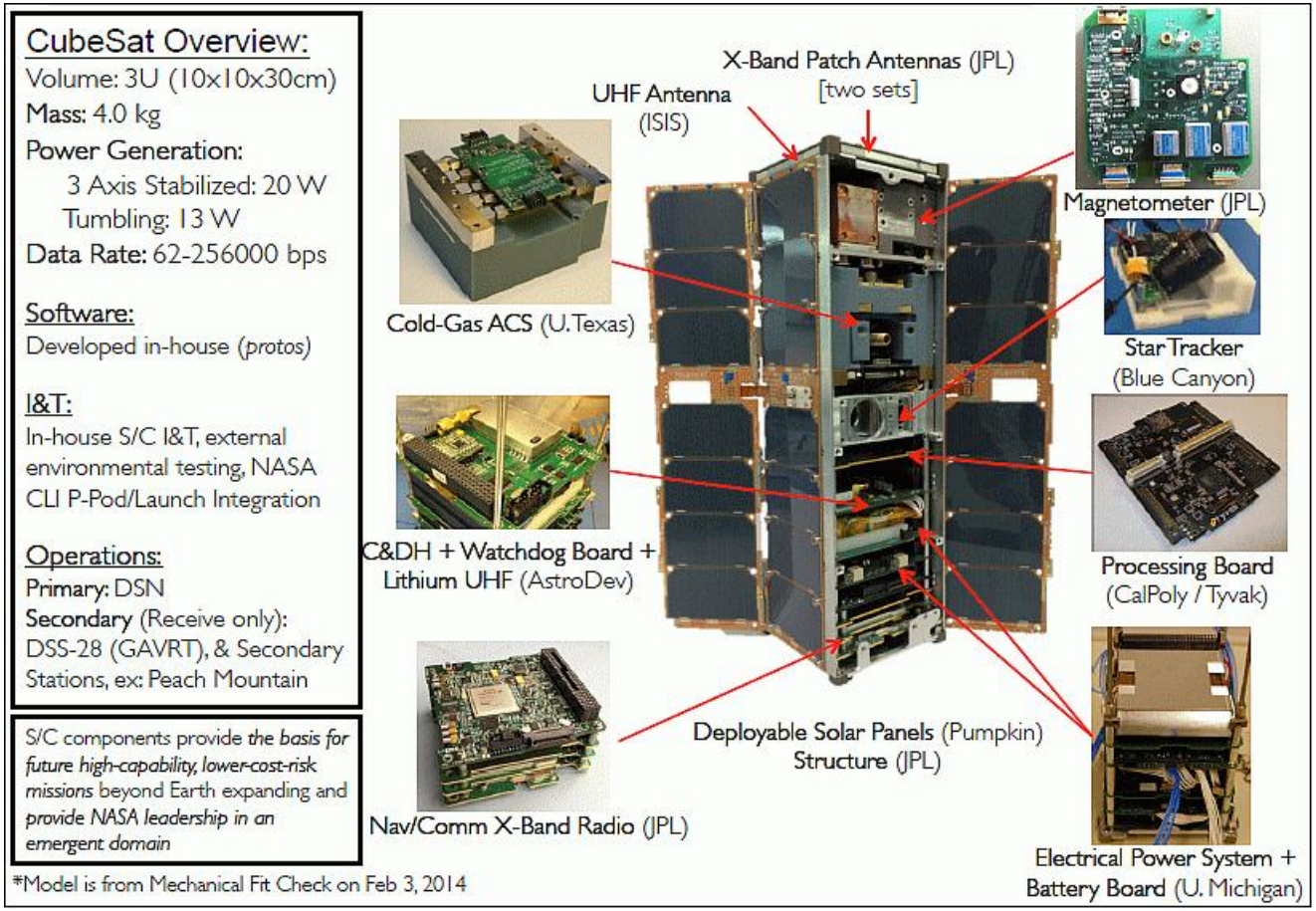
CubeSat Overview:
Volume: 3U (10x10x30cm)
Mass: 4.0 kg
Power Generation:
3 Axis Stabilized: 20 W
Tumbling: 13 W
Data Rate: 62-256000 bps

Software:
Developed in-house (*protos*)

I&T:
In-house S/C I&T, external environmental testing, NASA CLI P-Pod/Launch Integration

Operations:
Primary: DSN
Secondary (Receive only):
DSS-28 (GAVRT), & Secondary Stations, ex: Peach Mountain

S/C components provide *the basis for future high-capability, lower-cost-risk missions* beyond Earth expanding and *provide NASA leadership in an emergent domain*

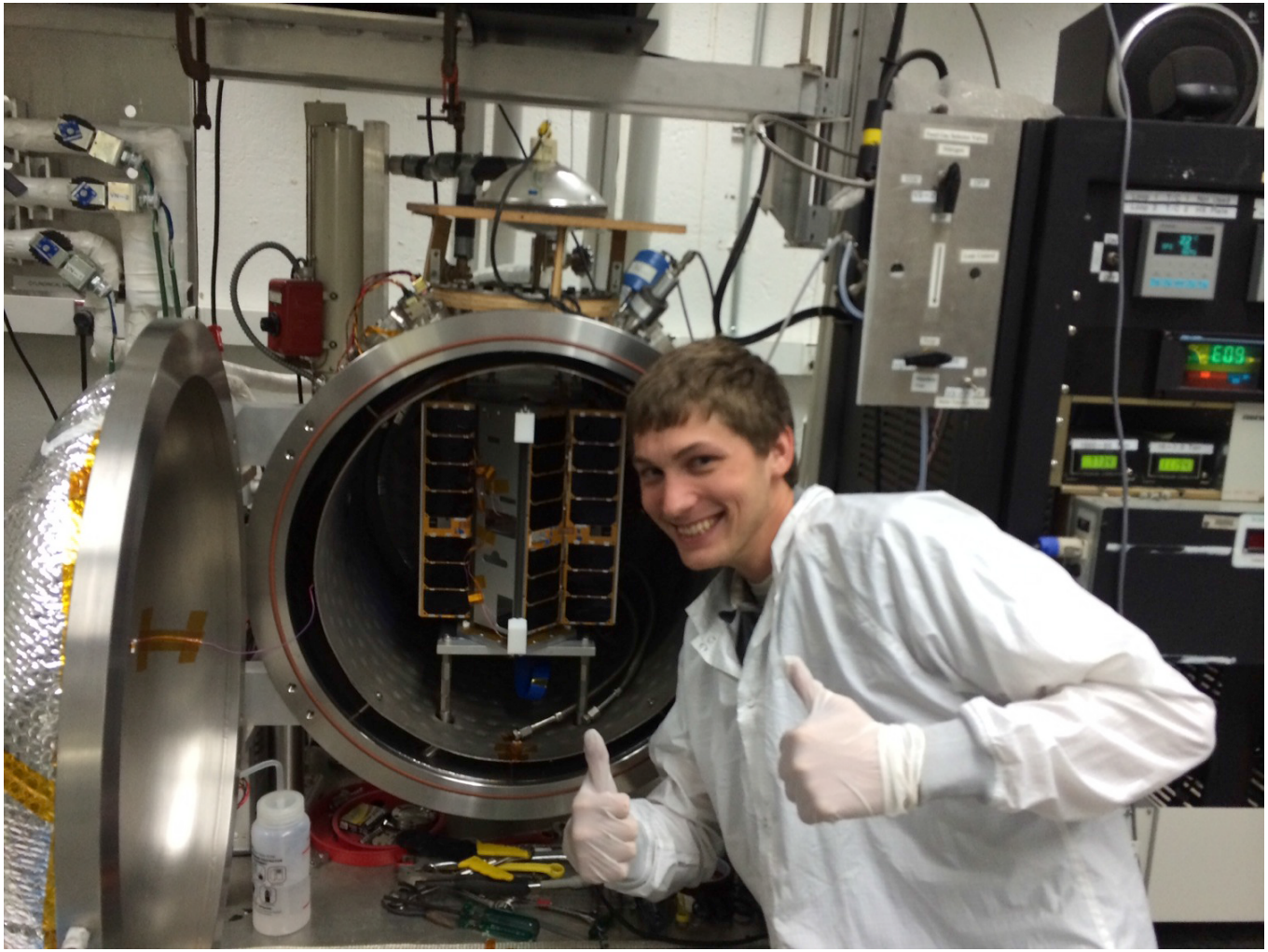


*Model is from Mechanical Fit Check on Feb 3, 2014

Image URL: https://directory.eoportal.org/documents/163813/1489551/INSPIRE_Auto4

TAYF: test as you fly

Really tiny …



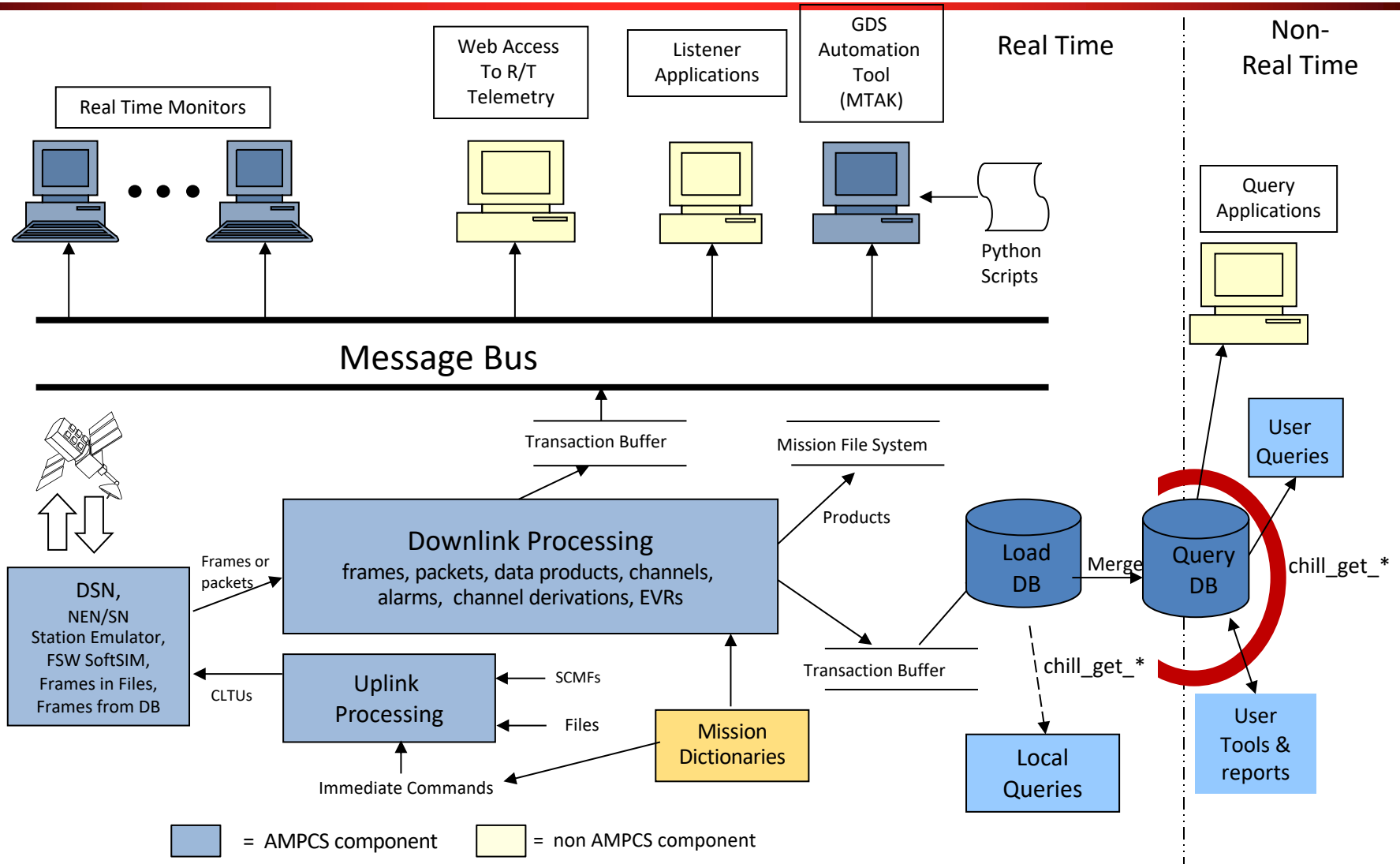
from: "INSPIRE (Interplanetary NanoSpacecraft Pathfinder In a Relevant Environment)" [2]

AMPCS Functional Overview

- **AMPCS is a scalable, full function, real-time telemetry processing and display system**
  - **During Phase E Operations:** Provides real time S/C telemetry display, telemetry product distribution with user query support (primarily for downlink operations)
  - **During FSW Development, TestBed and ATLO operations:** Provides the test tool for spacecraft integration and test (for both uplink and downlink operations)
- **Accepts CCSDS formatted in-sync frames or packets**
  - Sources: DSN, NEN/SN, a station emulator, files, or from the AMPCS Database
- **Processes frames or packets into telemetry products (channelized data, EVRs, Products, etc.) for delivery to real time and non-real-time customers**
- **Supports testbed and ATLO telemetry processing and commanding**
  - Test Session Orientation allows quick access to each test session's pertinent data
    - Captures all incoming and processed data, logs, FSW version used, and dictionary version used, etc.
    - Allows cross-test session analysis
  - Special test tool features to assist spacecraft integration and test (e.g. command fault injection, test session management, frame and packet watch displays, frame quality displays)
  - AMPCS Test Automation Toolkit (MTAK) for spacecraft test scripting and general automation
- **Provides real-time telemetry display**
- **Stores all telemetry artifacts allowing post-pass (and -test session) analysis**
  - Frames, Packets, EVRs, EHA, product metadata, logs, etc.

ATLO: Assembly, Test, and Launch Operations

AMPCS Overview



INSPIRE GDS Adaptation Strategy

- Accept constraints imposed by existing software to reduce cost, schedule, and risk
  - Avoid requiring features not already available
    - Follow CCSDS telecommand standards
  - Use AMPCS existing dictionary schemas
    - Still allowed full customization of dictionary content for: transfer frame definitions, telecommand packet definitions, APID definitions, decomm maps, channel definitions, channel derivation and calibration algorithms, command definitions
- Autogenerate software command handlers in the flight software from the ground system command dictionary at compile-time
- Establish portable and replicable environments, each rapidly reconfigurable
  - Both workstations and Virtual Machines

Cubesat-focused Lessons

- Small team, almost no funding
  - Take every opportunity to reduce risk – no way to recover
  - Test As You Fly reduces risks
    … but don't go overboard and lock everything down too early
  - Evolve the development environment with an eye on the operational configuration / environment
    - Use the same core applications from development through operations
- Accepting GDS-imposed constraints positively affected both cost and schedule
- Large complex applications can be difficult for a small team to configure and operate
  - Plan and budget for training, help, and consulting from the developers
- Don't let processes designed for big missions prevent you from getting your job done
  - Example: delivery from CM

Acknowledgements

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- This presentation heavily draws on a paper delivered at SpaceOps 2014 (citation below)

References

[1] William L. Quach, Lloyd R. DeForrest, Andrew T. Klesh, Joshua B. Schoolcraft, "Adapting a Large-Scale Multi-Mission Ground System for Low-Cost CubeSats," SpaceOps 2014, 13th International Conference on Space Operations, Pasadena, CA, USA, May 5-9, 2014, URL: http://arc.aiaa.org/doi/pdf/10.2514/6.2014-1634

[2] "INSPIRE (Interplanetary NanoSpacecraft Pathfinder In a Relevant Environment)," Proceedings of the 11th Annual CubeSat Developers' Workshop - The Edge of Exploration," San Luis Obispo, CA, USA, April 23-25, 2014, URL: http://www.cubesat.org/images/cubesat/presentations/Developers-Workshop2014/Klesh_INSPIRE.pdf

Questions?

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