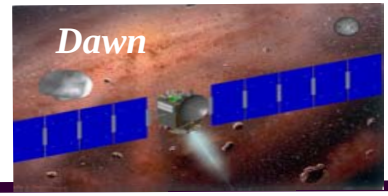
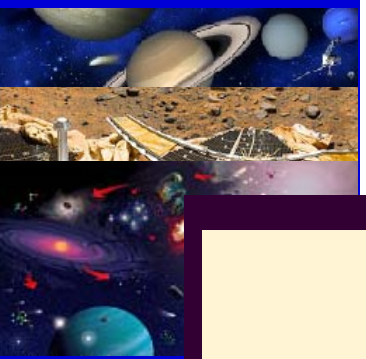
National Aeronautics and
Space Administration



Space Ops 2006



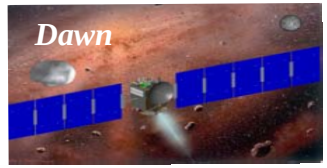
Zero to Integration in Eight Months, the Dawn Ground Data System Engineering Challenge

Lydia Dubon

June 21, 2006

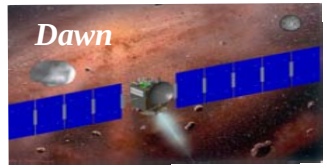
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Agenda



- Mission Overview
- Statement of Dawn GDS Engineering Challenge
- Systems Engineering Approach and Strategy
  - Requirements
  - Development Approach and Risk Management
  - Aggregation to Final Product
- Lessons Learned
- Conclusion

Dawn Mission Overview

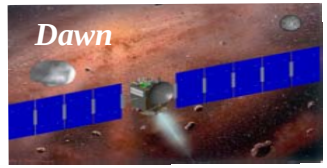


- Funded by the NASA Discovery Program. It is the ninth Discovery project.
- **Principal Investigator:** Dr. Christopher T. Russell (UCLA)
- **Implementing Organizations**: Jet Propulsion Laboratory, Orbital Sciences Corporation (OSC), Deutsches Zentrum Für Luft-und Raumfart (DLR) & Max-Planck - Institut für Sonnensystemforschung (MPS), Agenzia Spaziale Italiana (ASI)
- **Instruments:** Framing Camera (DLR/MPS), Mapping Spectrometer (ASI), Gamma Ray and Neutron Detector (LANL), Gravity Science (JPL)
- **Science:** To significantly increase our understanding of the conditions and processes acting at the solar system's earliest epoch, by examining the geophysical properties of complementary bodies, Vesta and Ceres, using imaging, spectroscopy, and gravity measurements.
- **Milestones**:

Launch Period	June 20 - July 10, 2007
Mars Gravity Assist	Mars 2009
Vesta Arrival	October 2011
Ceres Arrival	February 2015
End of Mission	July 1, 2015

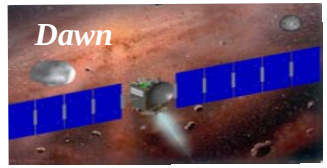
**** Courtesy of Dawn Chief Engineer , Marc Rayman***

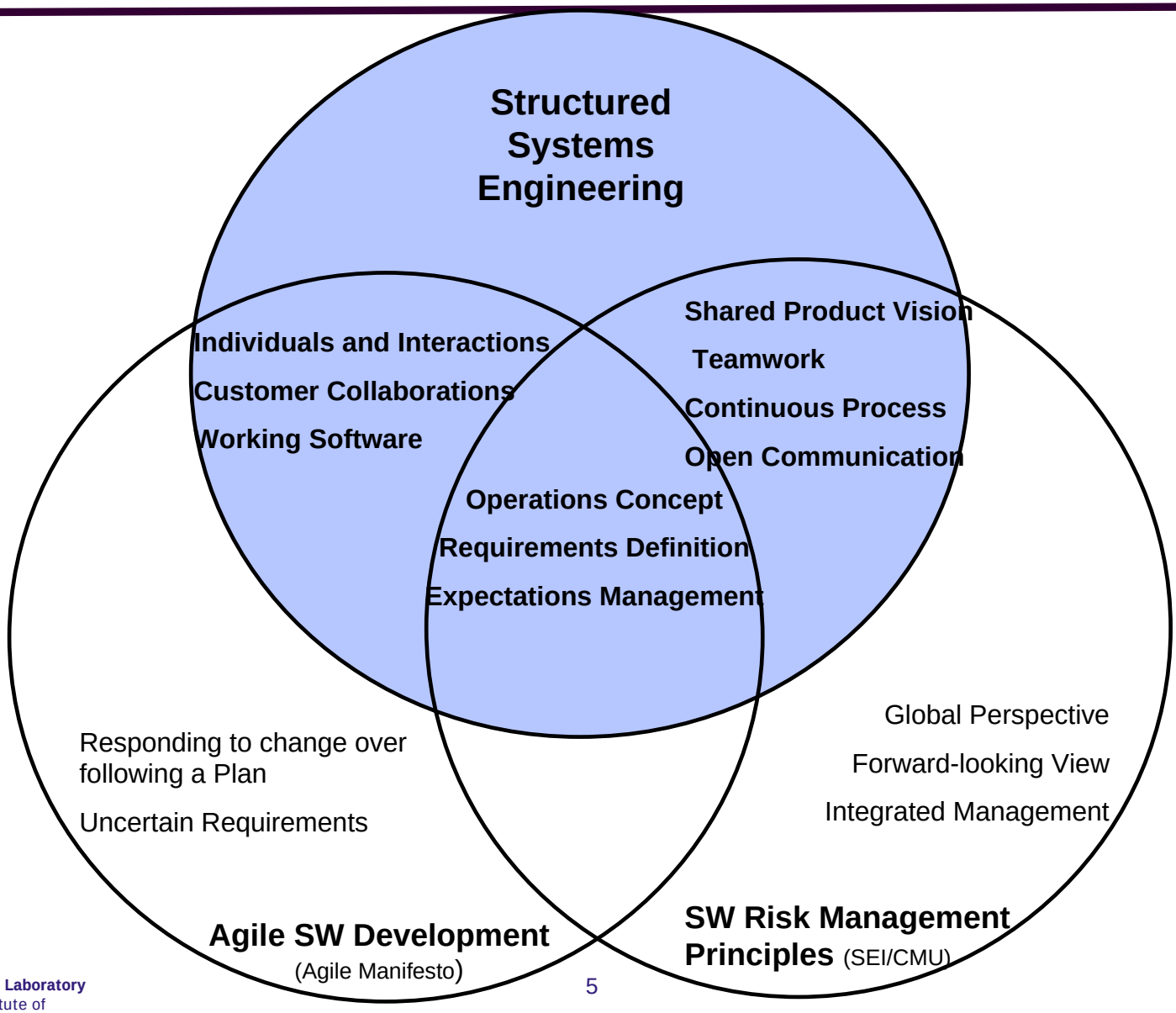
Statement of Dawn GDS Engineering Challenge



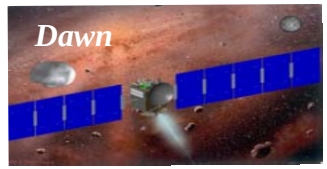
- GDS staffing began August 2003 with the focus on the Ground Segment Preliminary Design Review (PDR) milestone December 2003.
- During the first technical exchange between the JPL Ground Data System (GDS) Team and the OSC Flight Software (FSW) Team, August 2003, the need to integrate the GDS with the FSW in an OSC spacecraft simulator environment (SC Sim) was brought to the table.
- This requirement was driven by a project commitment to early instrument integration with the SC Sim by April 2004.
- An interface did not exist between JPL's ground system AMMOS (Advanced Multi-Mission Operations System) and OSC's flight system. In addition, OSC was to use its ground system for flight system test and integration. However, AMMOS was and is the ground system to be used in flight operations. An interface also did not exist between both ground systems.
- The Dawn GDS System Engineering challenge was to transition from a stare of zero design and implementation, and zero Deep Space experience with OSC, to a state of ground integration with OSC's SC Sim within eight months.

Structured Systems Engineering Approach and Strategy





Structured Systems Engineering Approach and Strategy



Mission System Requirements

Desired Ops Concept

Requirements Analysis & Risk Analysis

Viable Ops Concept

GDS 0.0 Stakeholders

Requirements

Functional Analysis & Flight/Ground Trade Analysis

Functional Decomposition

Driving Requirements

Flight/Ground Trade Results

Preliminary GDS System Design

Architecture w/ Interfaces

Design Validation & Assessment of Viable Solutions

System GDS 0.0

Managed Agile SW Engineering Processes

SW Eng Design

SW Eng Development

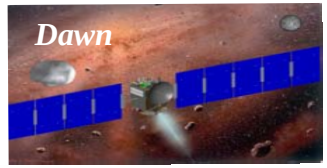
GDS Integration

Dawn Cmd/Tlm DB Translation

Dawn Test Controller Assistant

Dawn Cmd Generation Toolkit

Requirements



- GDS SC Sim integration request was decomposed into functional requirements ***aligned*** with GDS system-level driving requirements
- Early definition of a concise set of verifiable uplink & downlink requirements were defined for the Agile efforts.

GDS 0.0 Uplink:

- Provide interface for selection of instrument commands and parameters as defined in command database
- Generate flight-like AMMOS command files containing instrument commands
- Send Command Link Transmission Units (CLTUs) to S/C Simulator

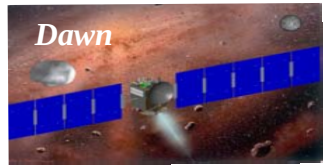
GDS 0.0 Downlink:

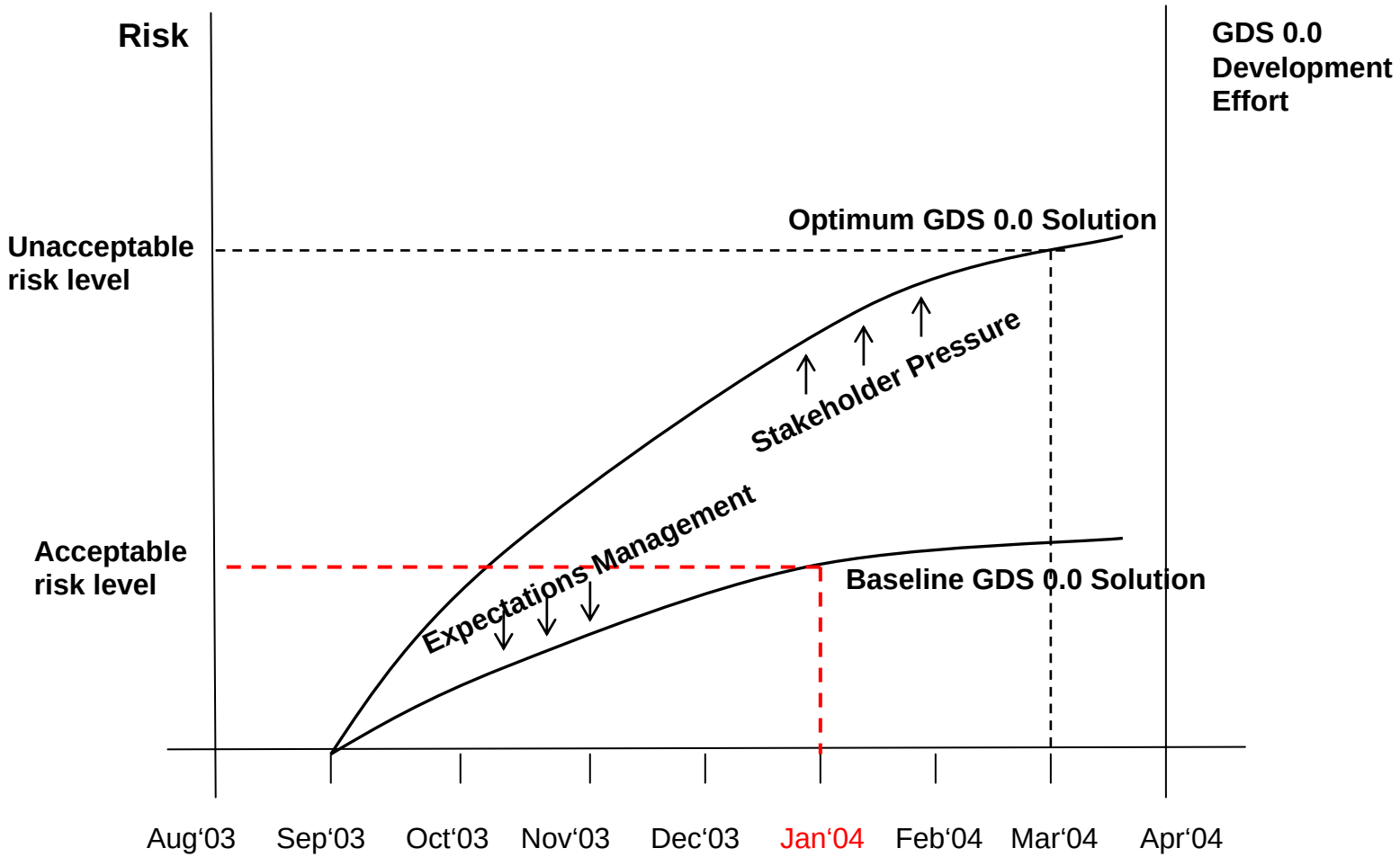
- Process frames from S/C Sim containing instrument packets
- Provide instrument telemetry channel extraction
- Display of telemetry channels as defined in the instrument telemetry database

System Level Driving Requirements

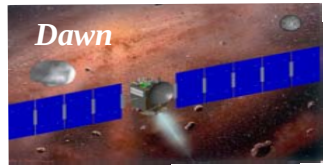
1. Advanced Orbiting System (AOS) Frame with Turbo Encoding
2. Translation of OSC Command & Telemetry Dictionaries
3. Delivery of Virtual Machine Language (VML) C structures to FSW
4. Support CCSDS standards implementation in OSC flight architecture
5. Support instrument and spacecraft file loads without on-board file system
6. Support distributed GDS data flows (JPL, OSC & UCLA)
7. Provide ITAR view of Ground/Mission data to foreign instrument teams

Risk Management Approach



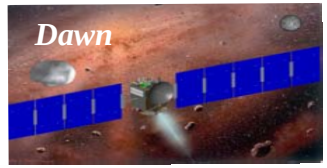


Integration of Multiple Ground Disciplines and Experts

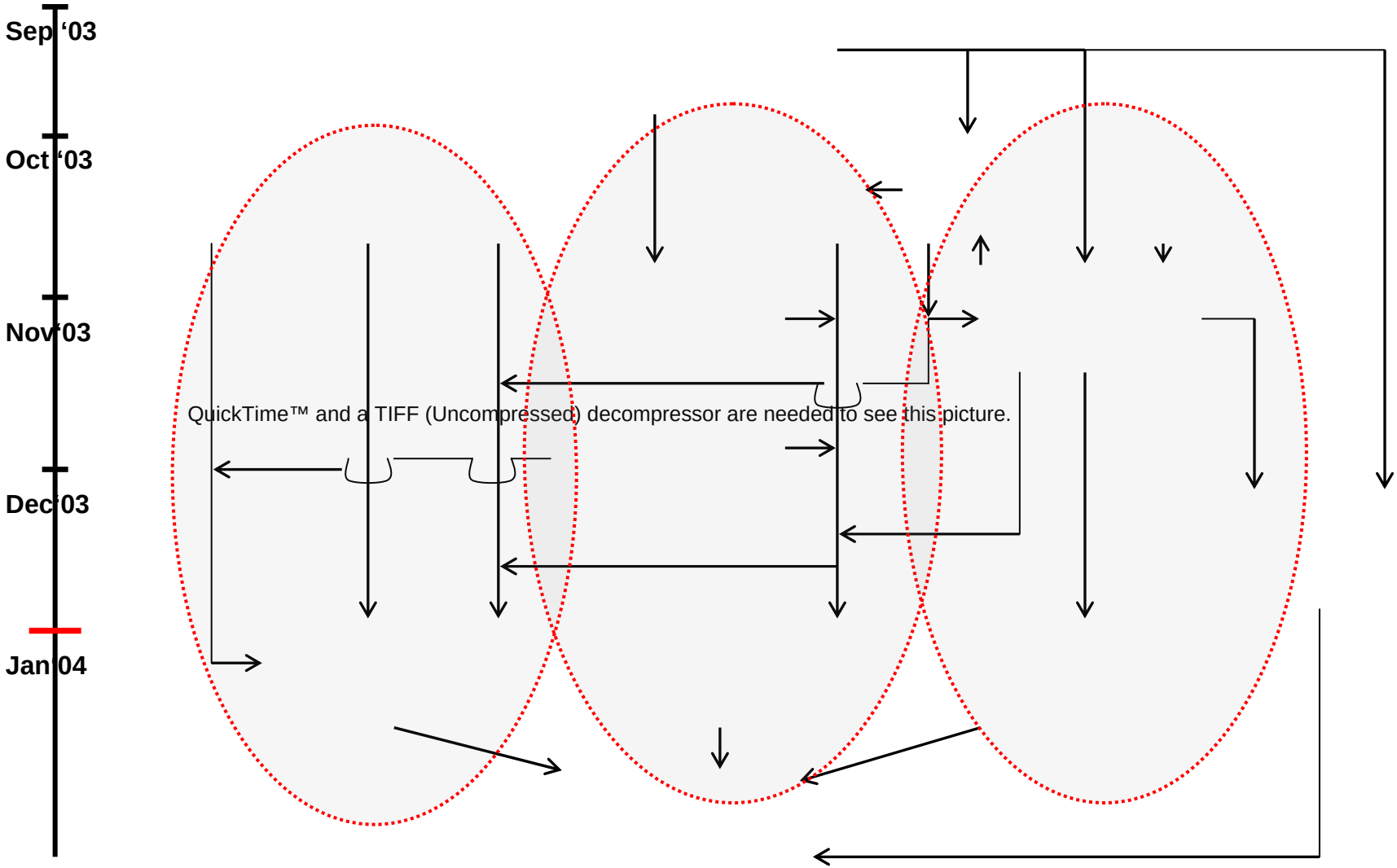


- The Systems Engineering approach integrated ground experts into a Dawn-focused effort with a common goal:
  - Two JPL domain experts were recruited: the authority on the AMMOS Multi-mission telemetry standard (Betsy Wilson), and the the authority on the AMMOS **C**ommand **D**efinition **L**anguage (Dung C. Doan)
  - The Mars Exploration Rover dictionary software architects and JPL Agile method practitioner (Jesse Wright) was enlisted to develop the Dawn Command and Telemetry database translation and management software
  - An experienced flight project sequence adaptation developer (James Goddard) led the Dawn Cmd Generation Toolkit
  - An experienced flight/ground software integration engineer (Magdy Bareh) led the Dawn Test Controller Assistant Toolkit effort
- The above experts worked both independently and as a team united under the systems engineering umbrella

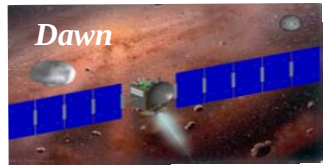
Agile-type Development Approach

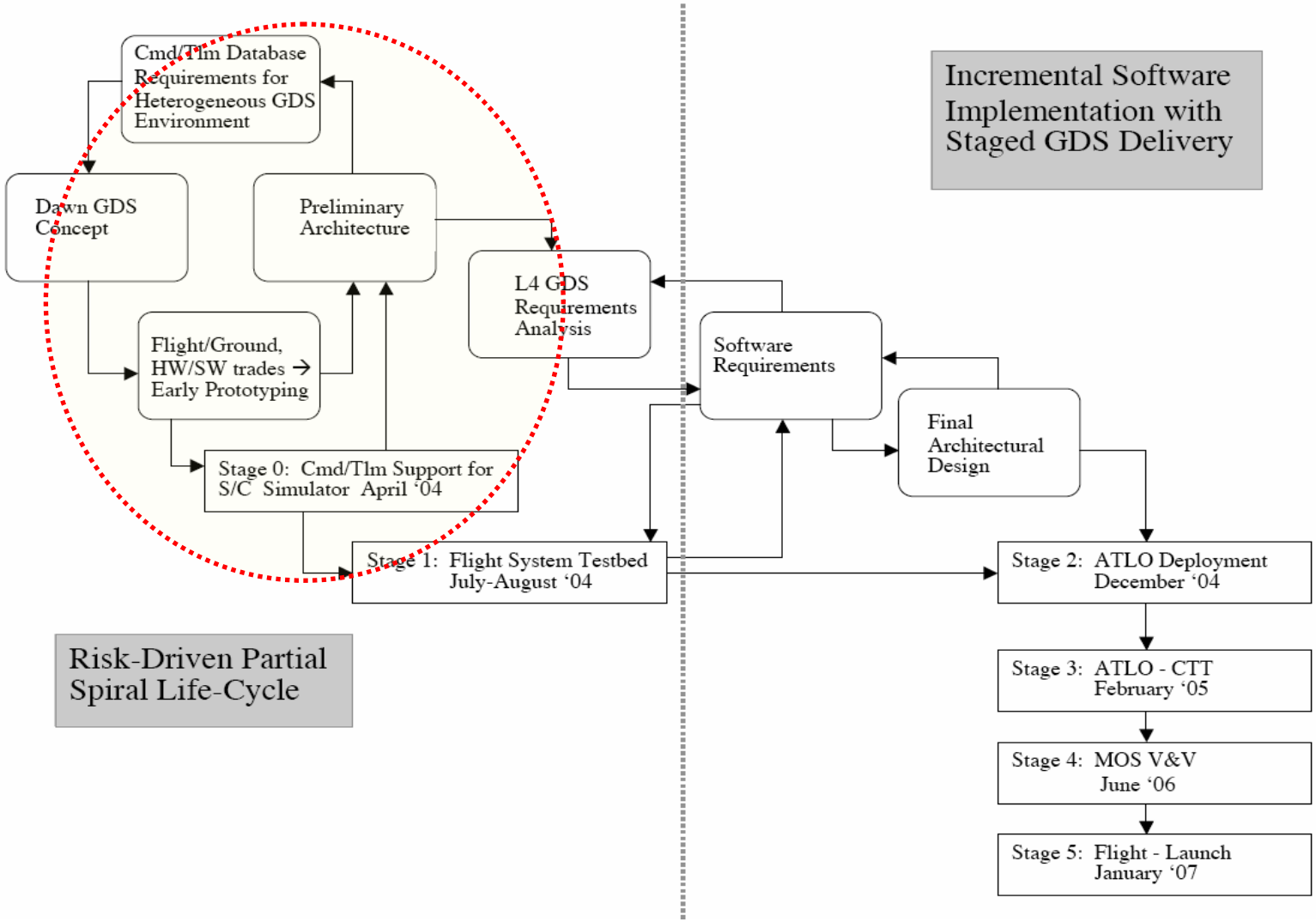


Space Ops June 20

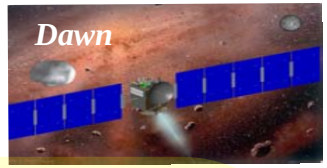


Systems Engineering Approach enabled early definition of GDS SW Life-Cycle





Systems Engineering Approach Facilitated Future DB Process Automation



OSC Flight Software

VML Flight C-strucs

JPL
OSC
UCLA
GDS Workstations

3 (tlm)

4

DOM (AMMOS)

C Strucs
VML CDL
ITAR CDL
CDL

Decomm Maps
Tlm Defs
Channel Tables
Channel Conversions
Alarms Event Msgs

JPL VMLCDL tool

3

OSC Cmd/Tlm Databases

Flight Tables

1

2

AMMOS Cmd/Tlm DB Products

OSC Database Translator

OSC Reformatted DB Files

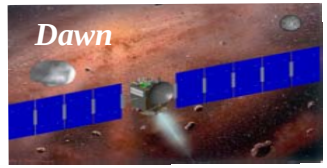
GDS 0.0

JPL Dawn Database Translation Tools (J. Wright)

Translated Output per OSC/JPL DB ICD

Automation

Aggregation to the Final Product



User provides Cmds with parameters or scripts of commands

GDS 0.0

Uplink Test Controller Assistant

Dawn Cmd Gen Toolkit

Telemetry Processor

Downlink Controller

JPL AMMOS

User views telemetry displays

CLTUs (uplink)

AOS Frames (downlink)

Telemetry Packets

User validates FSW behavior

OSC S/C Simulator

Telecommand Packets

Telemetry Packets

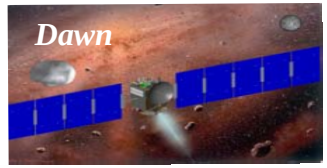
Instrument Simulator or Engineering Model

User validates instrument behavior

Instrument Ground Support Equipment

User analyzes instrument downlink data

Lessons Learned



- The overarching GDS systems engineering method enabled GDS 0.0 lessons learned to be fed into the overall Dawn GDS design and implementation approach

  Early Flight/Ground, Cmd/Tlm trade-offs with new spacecraft partner:

  - The GDS preliminary design and the telemetry and command trade-off agreements were validated with GDS 0.0
  - The gap between OSC's ground data system and JPL's ground system was breached with the database translation effort

  Requirements:

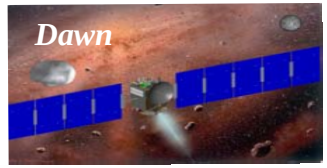
  - By aligning GDS 0.0 requirements with GDS driving requirements, four of seven key driving requirements were addressed with the GDS 0.0 barebones approach
  - In response to stakeholder inputs, GDS requirements were captured and folded into GDS requirements process

  Technical Partnerships:

  - The technical partnership that emerged between the JPL GDS Team and the OSC FSW Team has been instrumental to all future efforts

- By enforcing an overall systems engineering approach, GDS readiness for the Ground Segment PDR was not jeopardized. Furthermore, GDS contributions to the PDR were more technically comprehensive and sound

Conclusion



- The Dawn GDS Team met the SC Sim integration challenge in eight months. The GDS System Engineering approach in response to the SC Sim integration challenge, focused on a set of key practices: decomposition of project request into manageable requirements; integration of multiple ground disciplines and experts into a focused team effort; risk management thru management of expectations; and aggregation of intermediate products into a final product.
- By maintaining a a system-level focus, the overall systems engineering process unified team GDS Team members with a common goal: the success of the ground system as a whole and not just the success of their individual expert contributions. Incorporation of Agile-type development efforts were aligned with a risk strategy based on team-oriented principles and expectations management, thus achieving a more stable baseline solution without compromising the integrity of the GDS design.

It should be noted that other Systems Engineering domains such as Payload Systems and Science Operations Systems Engineering were key contributors to the overall success of the SC Sim integration challenge.