

Defining the Complex JPSS Ground System in Pieces Using DoDAF 2.0 as Implemented with UPDM

Robert Morgenstern¹

NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

Jeffrey L. Hayden² and Alan Jeffries³

Jeffries Technology Solutions, Inc., Herndon, VA 20170, USA

NASA is developing the Joint Polar Satellite System (JPSS) Ground System for NOAA. The architecture describing this complex system of systems is being modeled using DoDAF 2.0 as described by the Unified Profile for DoDAF and MODAF (UPDM) and by the System Modeling Language (SysML); both of which are based on the Unified Modeling Language (UML) developed for the software community. The JPSS Ground System is expected to provide command uplink, data downlink, data reduction, and processed data distribution for a disparate set of satellite missions, each of which provides the data from multiple sets of weather, climate, and environment measuring instruments. The program's ground stations are near the Earth's poles on Norway's Svalbard island and at McMurdo Station in Antarctica. The program also plans to make use of NOAA's Fairbanks station and Kongsberg Satellite Service's Antarctic station in Troll. These ground systems utilize global networks for sending the received data to several central data processing locations in the United States, as well as distributing select data to Darmstadt, Germany. The complexity of the JPSS program has been decomposed into a set of capability threads that are described diagrammatically in DoDAF capability, operational, and system views. This paper describes the breakdown of the JPSS program into threads, the development of the threads, presents example thread details, and illustrates inter-thread interaction. The use of MagicDraw, the diagramming tool for developing the architecture, will also be discussed.

I. Introduction

The Joint Polar Satellite System (JPSS) is the National Oceanic and Atmospheric Administration's (NOAA) next-generation operational Earth observation program that acquires and distributes global environmental data primarily from multiple polar-orbiting satellites. The program plays a critical role to NOAA's mission to understand and predict changes in weather, climate, oceans and coasts, and the space environment, which support the Nation's economy and protect lives and property. The JPSS provides operational continuity of satellite-based observations and products for the Suomi National Polar-orbiting Partnership (SNPP) satellite. The first of two JPSS satellites, JPSS-1, is planned for launch in FY2017 with JPSS-2 to follow.

In addition to its own satellites operating in the 1330 Local Time of the Ascending Node (LTAN) orbit, the JPSS Program also leverages partner assets for better global coverage. This includes the Department of Defense (DoD) operational weather satellites (in the 1730 LTAN orbit), European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Meteorological Operational (Metop) satellites (in the 2130 LTAN orbit) and Japanese Aerospace Exploration Agency (JAXA) Global Change Observation Mission (GCOM) satellites (in the 1330 LTAN orbit).

¹ System Architecture Lead, JPSS Ground Project, NASA Goddard Space Flight Center, Code 581, Greenbelt, MD 20771,

² System Architect, JPSS Ground Project, Jeffries Technology Solutions, Inc., 1517 Meadow Chase Drive, Herndon, VA 20170, AIAA Member

³ System Engineer, JPSS Ground Project, Jeffries Technology Solutions, Inc., 1517 Meadow Chase Drive, Herndon, VA 20170, AIAA Member

The JPSS Program also provides data acquisition and routing support to the Defense Meteorological Satellite Program (DMSP), the Coriolis/WindSat, the NOAA Polar-orbiting Operational Environmental Satellites (POES), as well as the National Aeronautics and Space Administration (NASA) Space Communication and Navigation (SCaN) supported missions, which include the Earth Observing System (EOS) series. In addition, JPSS provides internet access to McMurdo Station in Antarctica for the National Science Foundation. Moreover, the JPSS Program will build free flyer satellites and sponsor their operations to accommodate Total and Spectral solar Irradiance Sensor (TSIS) and service instruments such as Advanced Data Collection System (A-DCS), Search and Rescue Processor (SARP) and Search and Rescue Repeater (SARR), which may be supported by the JPSS Ground System (GS), or may have a simpler isolated ground system.

As a shared ground infrastructure, the JPSS GS supports the heterogeneous constellation of these polar-orbiting satellites both within and outside the JPSS program through a comprehensive set of services as listed in Table 1.

Table 1. JPSS Ground System Services

Service	Description
Enterprise Management and Ground Operations	Provides mission management, mission operations, ground operations, contingency management and system sustainment
Flight Operations	Provides launch support and early orbit operations, telemetry and commanding, orbital operations, mission data playback, payload support, flight software upgrade, flight vehicle simulation, and disposal at the end of mission life
Data Acquisition	Provides space/ground communications for acquiring mission data
Data Routing	Provides routing of telemetry, mission and/or operations data through JPSS' global data network
Data Product Generation	Provides the processing of mission data to generate and distribute raw, sensor, environmental, and ancillary data products
Data Product Calibration and Validation	Provides calibration and validation of the data products
Field Terminal Support	Provides development and operational support to the Direct Readout/Field Terminal users

The JPSS GS is complex, involving a large number of stakeholders, project processes and relationships with development contractors, as well as architectural modernization. To manage all this development, the program uses the MagicDraw UML software with SysML and UPDM plug-ins to exploit the tools of the Department of Defense Architecture Framework version 2.0 (DoDAF 2.0) to capture the architecture and communicate out to the community what it entails. In Ref. 1, we identified key aspects of how DoDAF 2.0 was used to manage and coordinate the development by identifying the JPSS GS organizational structure and performers; the actions performed by the organizational entities; the information that must flow among the entities; the systems, functions, and actions that enable realization of the JPSS capabilities; and, the information and data exchanged among performers and systems.

Since the JPSS GS is so complex, it was decided early on to break the architecture into more manageable pieces by defining it as a set of threads that each accomplish definable capabilities, yet are interdependent. The DoDAF 2.0 Capability Viewpoint (CV) addition to the framework has enabled us to tackle the JPSS GS architecture with a crew of four architects (to date), each able to work independently on different threads in the model.

II. JPSS Ground System Threads

The JPSS GS has been decomposed into the 31 threads shown in Figure 1. CV-2 JPSS Capability Threads. The 31 threads are included in 7 higher level general capabilities that match the services in Table 1. For this paper, we will follow the architecture development stages for defining the Stored Mission Data (SMD) Handling thread shown to be included in the Data Product Generation Service. Data from each sensor on a satellite is saved in the on-board solid-state recorder (SSR) during each orbit. The data in the SSR is called SMD and that sensor data is sent down to the JPSS GS polar ground stations at Svalbard, Norway; Fairbanks, AK; Troll, Antarctica or McMurdo, Antarctica.

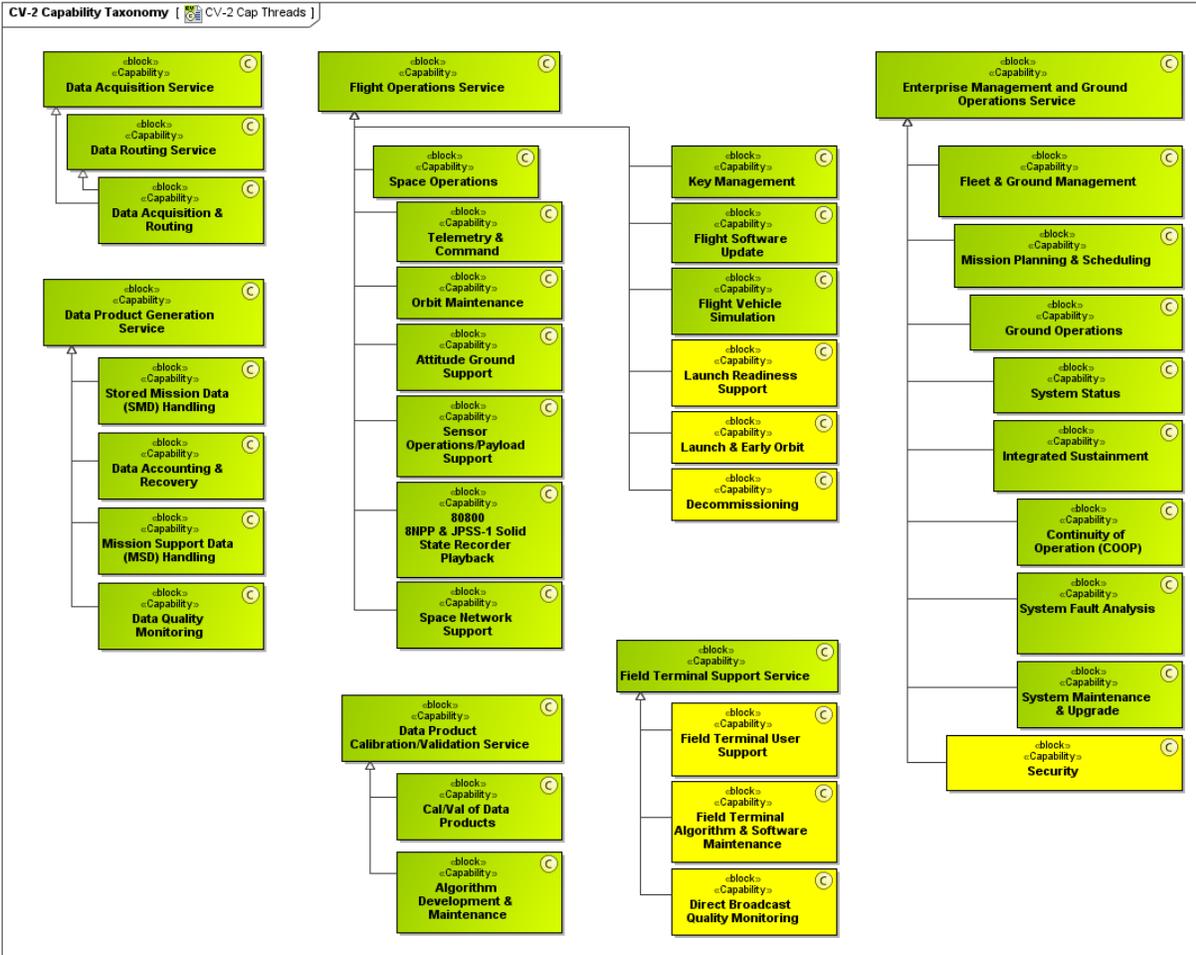


Figure 1. CV-2 JPSS Capability Threads.

This data is sent over international undersea and satellite networks to the NOAA Satellite Operations Facility (NSOF) in Suitland, MD; or to a common backup (CBU) facility in the Vertex Center at Technology Park in Fairmont, WV. The NSOF and the CBU extract the sensor data from the data stream into Raw Data Records (RDRs); perform calibration calculations and geolocation on the RDRs to generate Sensor Data Records (SDRs); and then combine the SDRs with supplementary forecasts into Environmental Data Records (EDRs). EDRs comprise the weather maps, climate maps, and other events of immediate interest, including forest fires and floods. Thus, the reduction and distribution of timely data by the SMD thread is the primary function of the JPSS GS.

The dependencies of the SMD thread with the other threads are shown in Figure 2. CV-4 JPSS Thread Dependencies, with the SMD Handling thread capability highlighted with a red ellipse. The SMD thread is dependent on 3 threads: SMD information/data from the Suomi-NPP and JPSS-1 SSR Playback which manages the satellite's on-board recorder pointers; the Mission Support Data (MSD) thread that brings in ancillary data from external entities and auxiliary data from internal systems; and the Data Accounting & Recovery thread that ensures all data received on the ground reaches its intended destinations. Six threads depend on information or data that are

generated internally to the SMD thread. The dependent threads are: Orbit Maintenance – which needs the SMD’s tank, thruster, and orbit telemetry information; Telemetry & Command – which needs stored telemetry information to ensure completeness of the telemetry used to verify the telemetry is working and that commands were received

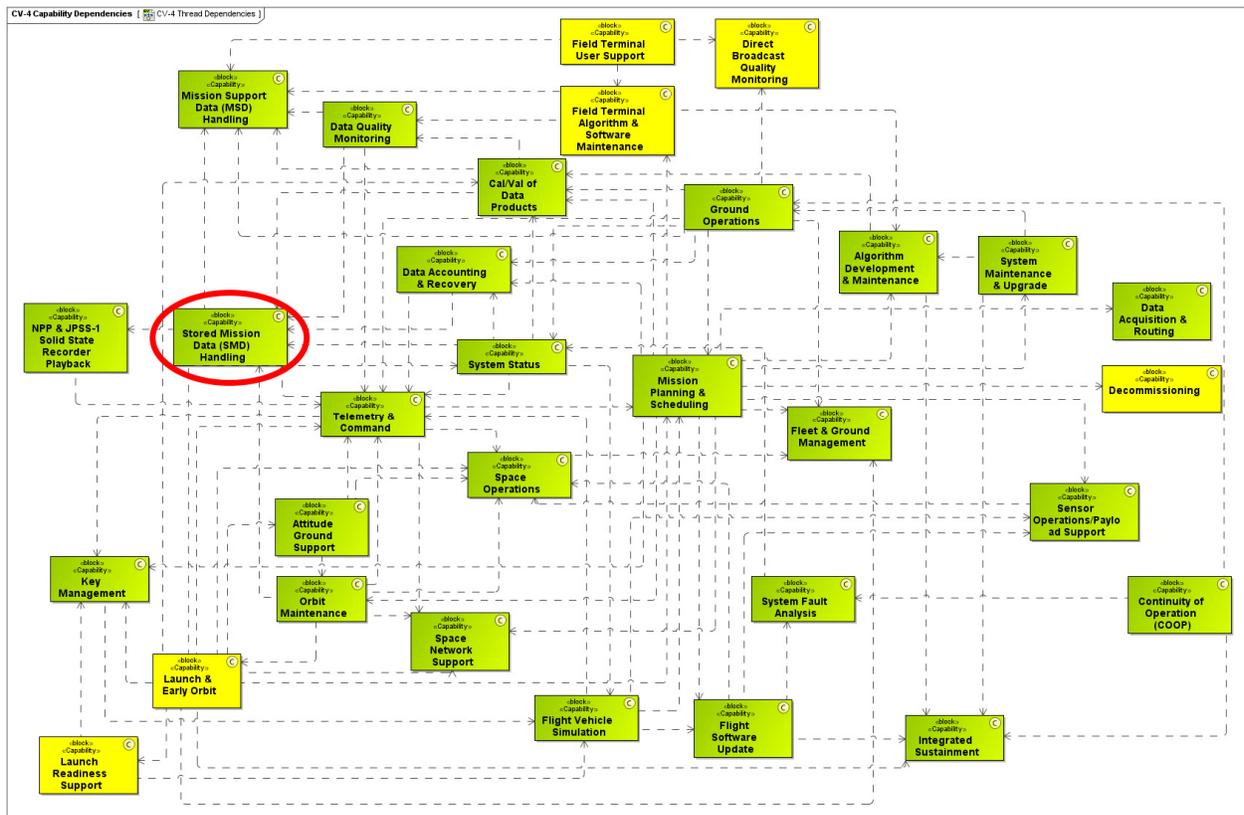


Figure 2. CV-4 JPSS Thread Dependencies

and executed; System Status – which uses the telemetry to determine the health of the spacecraft and its sensors; Data Accounting & Recovery – which needs the telemetry to determine if there is missing data which generates a retransmission of the missing data.; Data Quality Monitoring – which uses the SMD thread’s production data to assess the quality of the processes; and, Cal/Val of Data Products – which uses the SMD data products to determine how well the data processing algorithms are working and to check the validity of new or revised algorithms.

III. JPSS Operational Activities Performed in the Stored Mission Data (SMD) Thread

The Operational views are abstracted concepts of how the system is to function. The operational activities are the functional containers with information exchanges between them. The OV-5a view is used to illustrate the relations between the activities as well as the association of the activities with particular performers, as shown in Figure 3. We use color coding to differentiate performers within the JPSS Ground System (blue), supporting performers (purple), programmatic performers (orange), data consuming performers (red), or data providing performers (green).

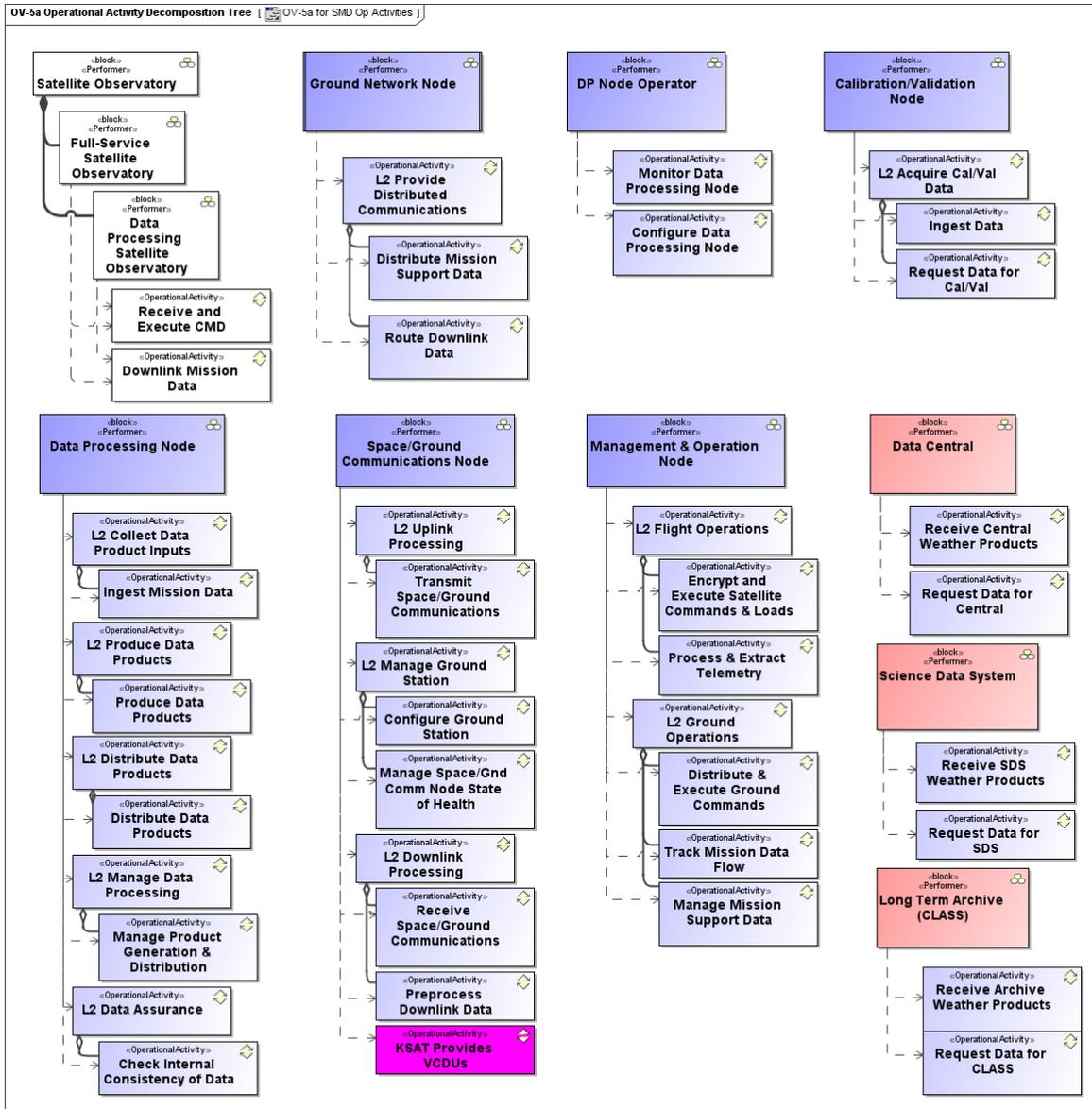


Figure 3. OV-5a JPSS Operational Activity Decomposition Tree for the SMD Thread

Each concept of operations (ConOps) thread (or use case) is documented within an OV-5b Operational Activity Model view, as seen in Figure 4 for the SMD Handling thread. The operational activities are put into swimlanes for each performer, which helps identify interfaces. The activities are linked to the ConOps descriptions and functional and performance requirements of the system. A requirements management tool is used to trace the requirements to these activities and actions within the ConOps.

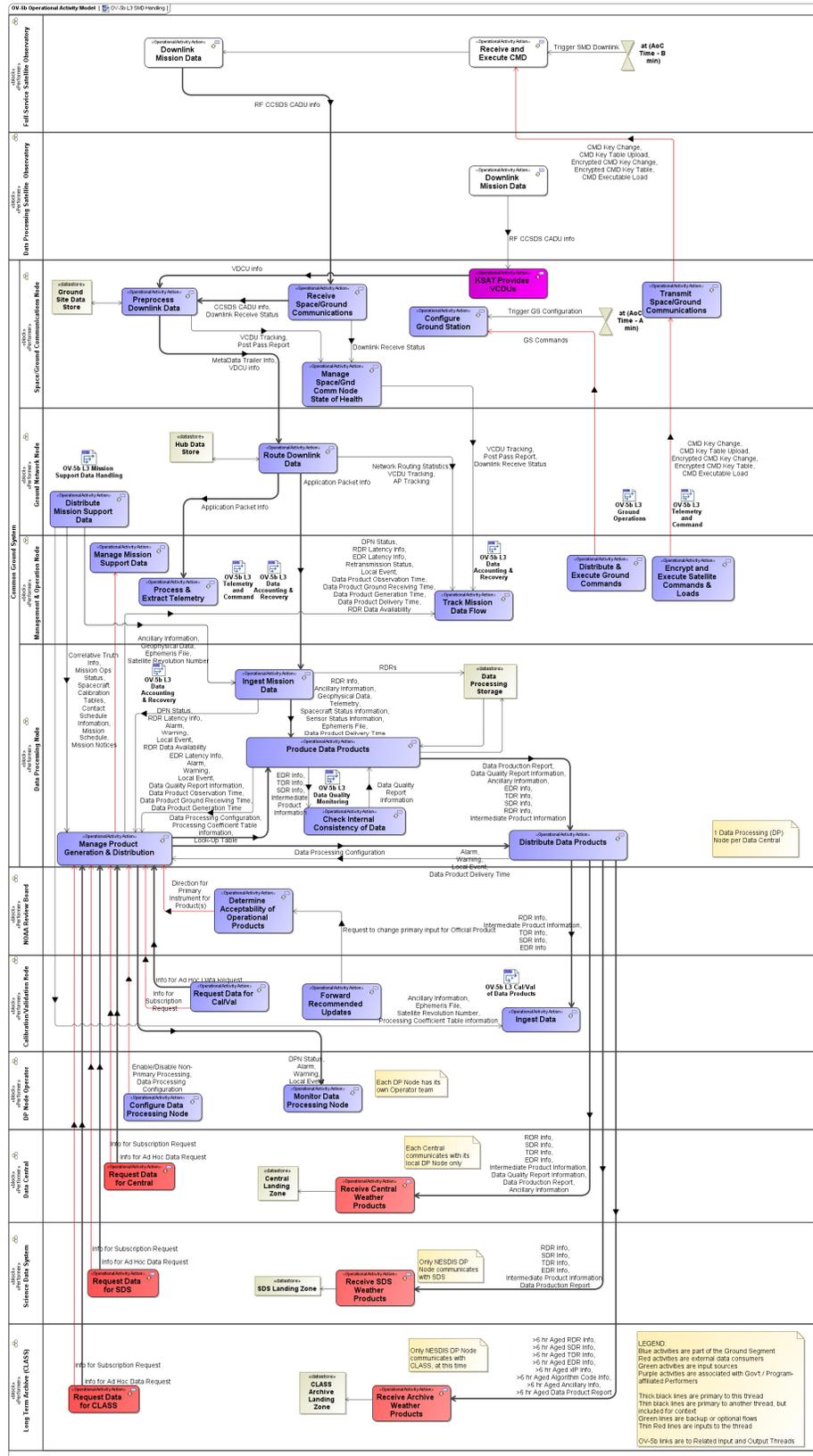


Figure 4. OV-5b Operational Activity Model for the SMD Handling thread

IV. JPSS Systems

While the operations views are abstracted for requirements, the system views are focused on implementation. In a similar role to the OV-5a for operational performers and activities, the SV-4 System Functional Hierarchy view, seen in Figure 5, serves to illustrate the relations between the functions as well as the association of the functions with their particular systems.

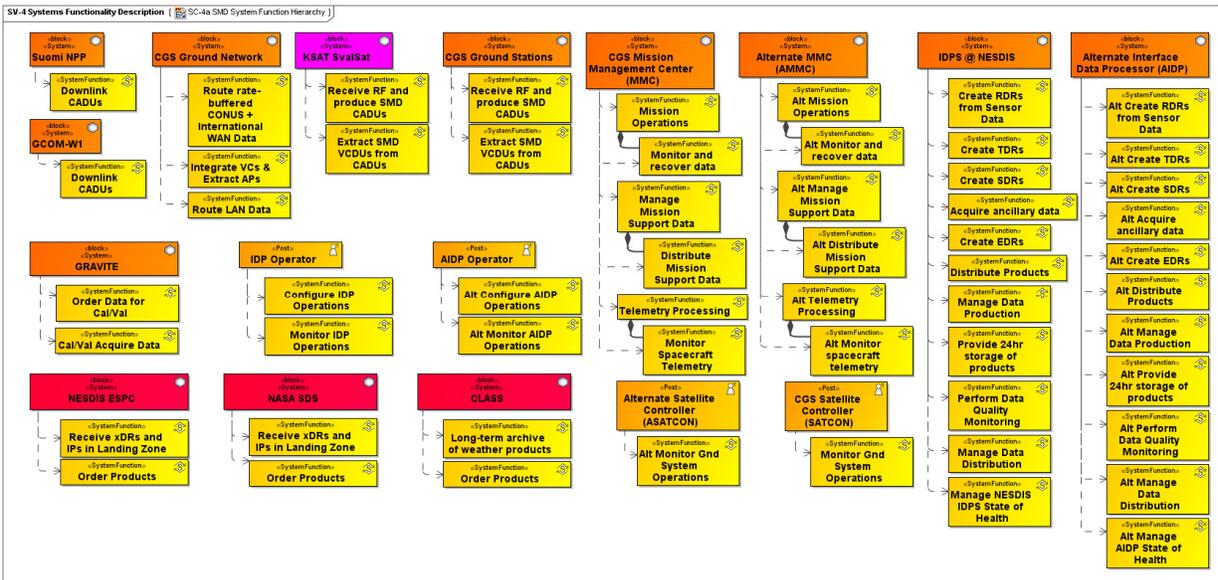


Figure 5. SV-4 System Function Hierarchy Subsetted for SMD Handling

The OV-5b view is translated from the abstract into the realized in the SV-4 System Functional Flow Diagram view, a cutout of which is illustrated in Figure 6, using system function activities in place of operational activities, and data exchanges in place of information exchanges. The operational performers that own the swim lanes are, instead, owned by the systems, organizations and posts that actually will fill the roles. Figure 6 illustrates how the Data Processing Node of Figure 4 is replicated into the Integrated Data Processing Segment (IDPS) and Alternate IDPS. Furthermore, the abstracted 'Produce Data Products' operational activity is realized by more detailed system functions for each data product type.

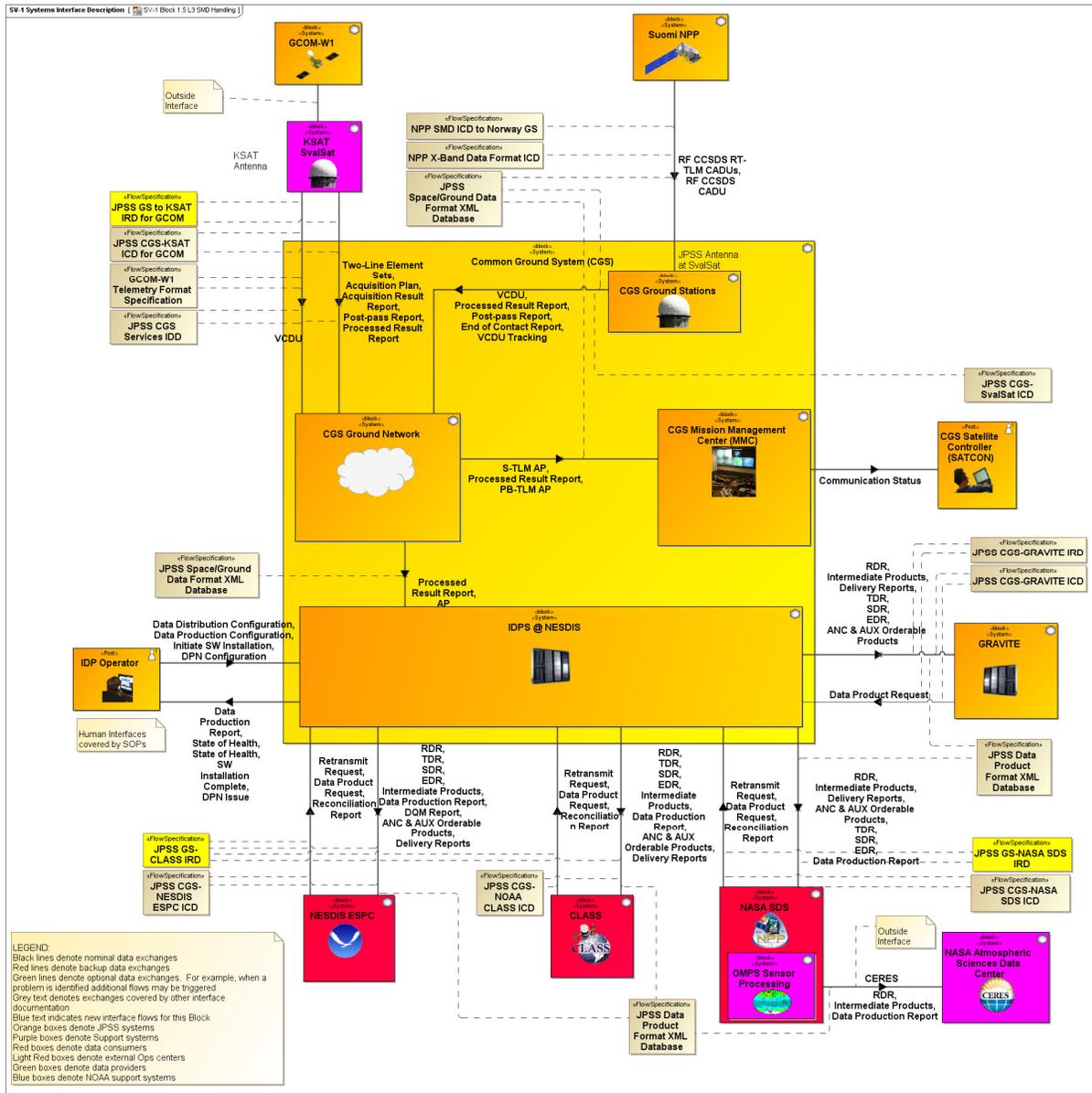


Figure 7. SV-1 System Interface Description for the SMD Handling Thread

For each thread, a SV-1 System Interfaces Diagram is generated, as shown in Figure 7. This view is generated by extracting from the enterprise SV-1, illustrated in Figure 8, only the inter-system/organization/role exchanges. It is not expected for Figure 8 to be readable at this page size. Please contact the authors for a larger resolution image if you want to see the details. This view highlights the interfaces associated with a particular thread. We have further expanded the utility of the view by allocating the flow to the identified interface documents that we've identified on a SysML package view to help manage our technical baseline.

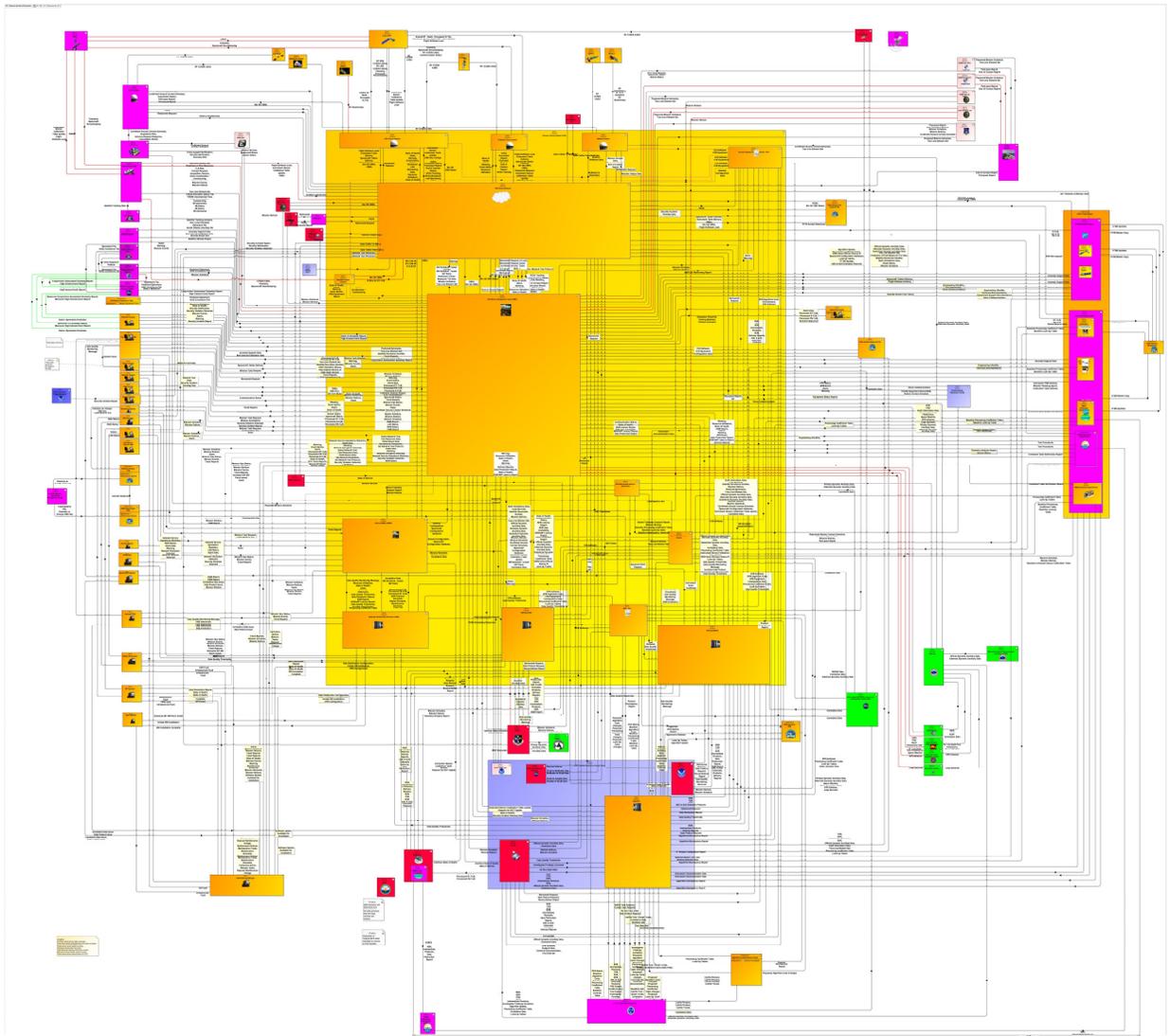


Figure 8. SV-1 System Interface Description for the JPSS Ground System Enterprise.

Once we have the thread-specific views, we can then create SV-1 views specific to all exchanges between the JPSS Ground System and some external party, as illustrated in Figure 9 for the case of NOAA’s Environmental Science Processing Center (ESPC). These views are used to drive the development of the Interface Requirements Documents (IRDs). These diagrams are used to hold discussions with the associated stakeholder to work out the details of the data flows. The SV-1 IRD views are contained within the IRDs along with an associated SV-6 System Data Exchange Matrix, which documents the flows in a tabular format, as shown in Table 2.

Table 2. SV-6 System Interface Table showing GS interfaces to NOAA's ESPC.

#	Interface Name	Data Items Exchanged	Sending Performer	Receiving Performer	Producing Function	Consuming Function
1	MSD Mission Notice Out to ESPC	 Mission Notices	 JPSS GS	 NESDIS ESPC	 Distribute Mission Support Data	 Receive Notices for Centrals
2	MSD Mission Schedule Out to ESPC	 Mission Schedule	 JPSS GS	 NESDIS ESPC	 Distribute Mission Support Data	 Receive Notices for Centrals
3	Input ANC ESPC-ADRS to MSDSvc	 Primary Dynamic Ancillary Data  Alternate Dynamic Ancillary Data	 NESDIS ESPC	 JPSS GS	 Provide Ancillary Products	 Collect Mission Support Data
4	Input Orbit ANC ESPC-ADRS to MSDSvc	 Space Weather  Earth Orientation Data  GPS Almanac  Leap Seconds	 NESDIS ESPC	 JPSS GS	 Provide Ancillary Products	 Collect Mission Support Data
5	Interface SOH ESPC to CGS	 Interface State of Health	 NESDIS ESPC	 JPSS GS	 Manage Central	 Collect & Monitor GSyS State of Health Data
6	SOS ESPC to CGS	 State of Service	 NESDIS ESPC	 JPSS GS	 Manage Central	 Collect & Monitor GSyS State of Health Data
7	Data Out CGS IDPS to ESPC	 RDR  TDR  SDR  EDR  Intermediate Products  Data Production Report  DQM Report  ANC & AUX Orderable Products  Delivery Reports	 JPSS GS	 NESDIS ESPC	 Distribute Products	 Receive xDRs and IPs in Landing Zone
8	DQM Message CGS IDPS-N to ESPC	 Data Quality Monitoring Message	 JPSS GS	 NESDIS ESPC	 Perform Data Quality Monitoring	 Receive Notices for Centrals
9	Retx Req ESPC to CGS IDPS	 Retransmit Request	 NESDIS ESPC	 JPSS GS	 Receive xDRs and IPs in Landing Zone	 Manage Data Distribution  Distribute Products
10	Data Product Request ESPC to CGS IDPS	 Data Product Request	 NESDIS ESPC	 JPSS GS	 Order Products	 Manage Data Distribution
11	Reconciliation Report from ESPC to CGS IDPS	 Reconciliation Report	 NESDIS ESPC	 JPSS GS	 Receive xDRs and IPs in Landing Zone	 Manage Data Distribution

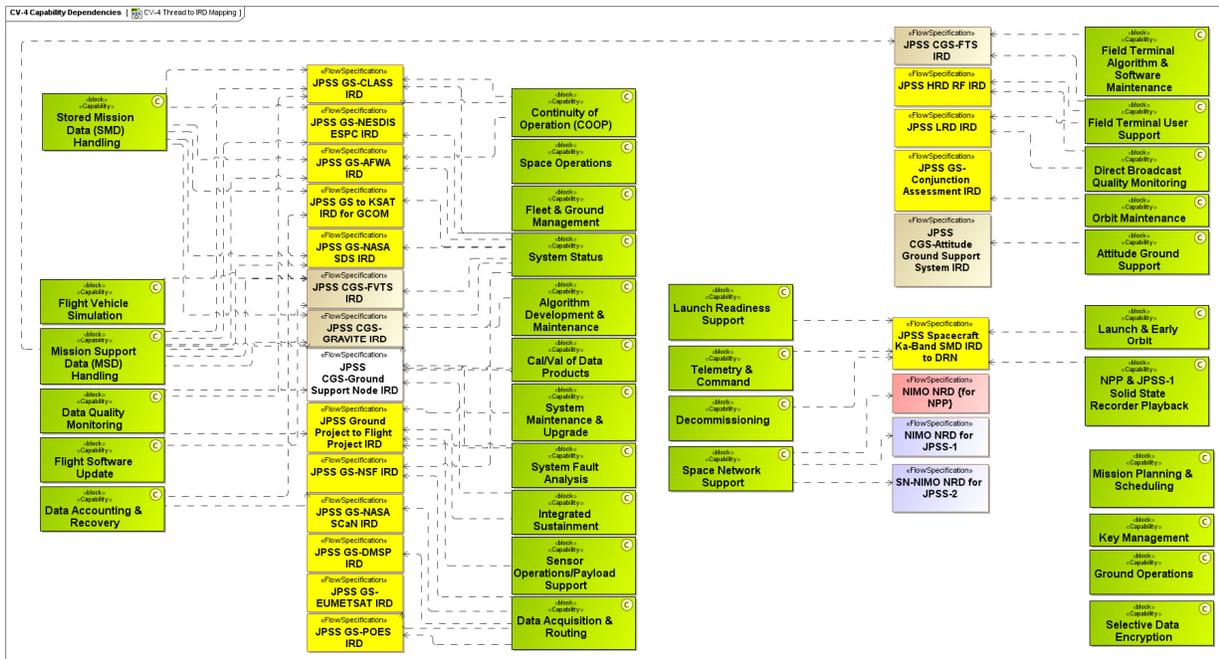


Figure 10. CV-4 Capability Thread to Interface Requirements Document (IRD) Mapping.

To assist in tracking impacts, a CV-4 Capabilities Dependency view is used to track the relations between these threads and the Interface Requirements Documents (IRDs), as shown in Figure 10. This view helps one to understand impacts as the threads evolve or the interfaces develop based on meetings with the relevant stakeholders. It's a good graphical representation of which capabilities have coverage in each IRD.

V. Conclusion

Decomposing a very large project into identifiable and semi-independent activity threads, and then parsing those threads out to individual members of a team, has been very helpful for developing the complex overall architecture of the JPSS Ground System program. The UPDM, SysML, and UML tools in the cross-platform MagicDraw are able to handle the JPSS Ground System which is now 350 (and still growing) architecture diagrams, tables, and matrices with a modern PC or Macintosh with at least 8 GB of RAM.

The use of the DoDAF viewpoints in presenting architecture concepts to a project's management, stakeholders, and implementers, is proving to be very informative to those personnel. There is resistance at first to the techniques because it takes a while for uninitiated people to understand what they see. However by rigidly following the UPDM diagramming precepts, which do follow the software world's UML techniques, the program's people do come to understand and to contribute to the model itself. On JPSS the model's diagrams and tables are being inserted into the program's concept of operations and interface definition documents. It is anticipated that the model's features will be used for contract and data management in the next stage of JPSS development when the legacy systems are modernized.

References

¹ Hayden, J. L., and Jeffries, A., “On Using SysML, DoDAF 2.0 and UPDM to Model the Architecture for the NOAA’s Joint Polar Satellite System (JPSS) Ground System (GS),” *AIAA Meeting Paper Submitted Electronically*, AIAA SpaceOps 2012, Stockholm, Sweden, 11-15 June 2012.