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NASA DIRECT BROADCAST
FOR
REAL-TIME REMOTE SENSING APPLICATIONS

Executive summary

Enabling real-time data access of Earth remote sensing data has been NASA's Direct Readout program's primary objective. Through the use of Direct Broadcast (DB) on EOS and S-NPP satellites, real-time environmental data is made available on a continuous basis world-wide. Having regional data access, three additional elements are necessary to render DB data useful by the general application user: instrument specific algorithms along with data processing tools to handle a live data stream, data product formatting or data transport tools and, product distribution mechanisms for decision support systems. This paper addresses these elements and their availability to the public as NASA's contribution to enabling the use of space-borne remote sensing data for real-time applications.

NASA Direct Broadcast For Real-Time Remote Sensing Applications

1 INTRODUCTION

Beginning in the mid 80's, NASA's primary interest in Direct Broadcast (DB) has been in the demonstration of practical applications of Direct Readout (DR) ground system technologies, including real-time data distribution, data mining, distributed processing, and dynamic data management. These technologies combined with access to DR science processing algorithms (SPA)s have been playing an increasing role in temporal studies and tactical applications such as volcanic eruptions and plume tracking, sand storm dust distribution, snow and ice distributions, fire detection, weather nowcasting, polar winds, to mention a few. In the evolution of direct readout three things became evident in order to provide value to real-time data access: availability of freely transmitted instrument direct broadcast data – global data dissemination, or network-accessible near-real-time data sets from local or centralized data sources, access to direct readout science application algorithms and a decision-making infrastructure that makes use of DR results, including information dissemination mechanisms to increase information availability for temporal and tactical remote sensing monitoring.

NASA has defined Direct Broadcast (DB) as the real-time transmission of satellite instrument data to the ground; as the Earth is observed by satellite instruments, data is formatted and broadcast omni-directionally in a hemispheric pattern to Earth in real-time. NASA's DB satellites that operate in this mode include Terra, Aqua, S-NPP and Aura (limited); continuously transmitting all their instrument data to the ground, with the exception of Terra which transmits only MODIS. Direct broadcast satellites are no different than ones that don't have it, except for a secondary data path from the CCSDS data packaging module to the RF sub-system. Their differences are primarily in their ability to divert data packets directly to the RF downlink sub-system which gives no delay of observed data to the ground. Users who have compatible ground receiving equipment or Direct Readout (DR) systems and, are in direct line of sight to these satellites may receive these transmissions, see **Figure 1.1** for technical ground system details. DR, on the other hand, is the process of acquiring freely transmitted live satellite data and/or network-accessible near-real-time data. As DR technologies become more affordable and accessible - such as with the onset of the Internet world-wide - tools have been developed by the remote sensing community to make satellite data and products easier to acquire (such as NASA LANCE), process, and utilize. As a member of this community, NASA supplies many of these tools to foster global data exchange, scientific collaboration and a means for real-time environmental monitoring.

1.2 NASA's Direct Readout Model

In order to understand the needs of a geographic region, in terms of information necessary to deal with specific environmental issues, it is necessary to have a communication's path to those that can provide assistance. Additionally it is necessary to have an interpretation mechanism by which information requirements can be mapped to an organization's remote sensing mission, science algorithm development and programmatic priorities that dictate a schedule for when, if at all, specific developments are, and can be made available to the general public. The Direct Readout Laboratory (DRL) at NASA GSFC plays this role, as the intermediary between remote sensing missions, such as Terra, Aqua, S-NPP, JPSS, and the DB community. The DRL encourages communication and maintains an open-door policy with the commercial and research and development sectors. This two-way information exchange is part of NASA's DR model, depicted in **Figure 1.1**. This model provides the DRL with critical information on the equipment currently in use, the technology being developed commercially, and the needs of the direct broadcast community. As a result, the DRL is able to report the "state of the community" to the NASA mission while providing the DB community with a two-way dialogue between the mission objectives and the user needs.

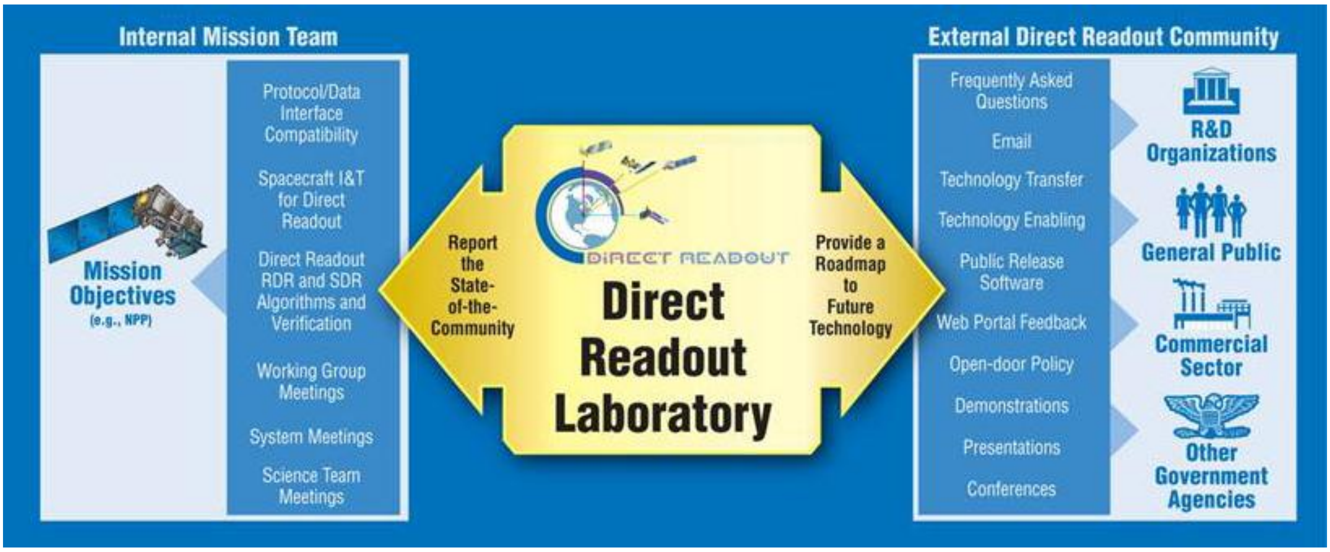

Figure 1.1 Roadmap to Direct Broadcast Data Usage

2 DERIVED DIRECT READOUT TECHNOLOGIES

One of the primary results of the DR model, as described in **Figure 1.1**, is the identification of key technology categories that the DR end-user would have to contend with in order to be compliant with a multi-satellite and multi-instrument environment. These categories include: real-time system processing tools, CCSDS packet re-assembly and standard data reformatting tools, instrument-specific calibration and geo-registration algorithms, a science processing algorithm-wrapping schema - for standard system integration and sustainment - and, real-time data distribution mechanisms. NASA has addressed these key technology categories in the form of specific technologies which are generic in nature and can be integrated into existing or developing DR systems.

DR technology development follows a very focused roadmap which address the key areas defined above. These technologies have evolved over time to include characteristics in data and transmission schemas unique to every instrument and spacecraft as decribed in **Figure 2.1**.

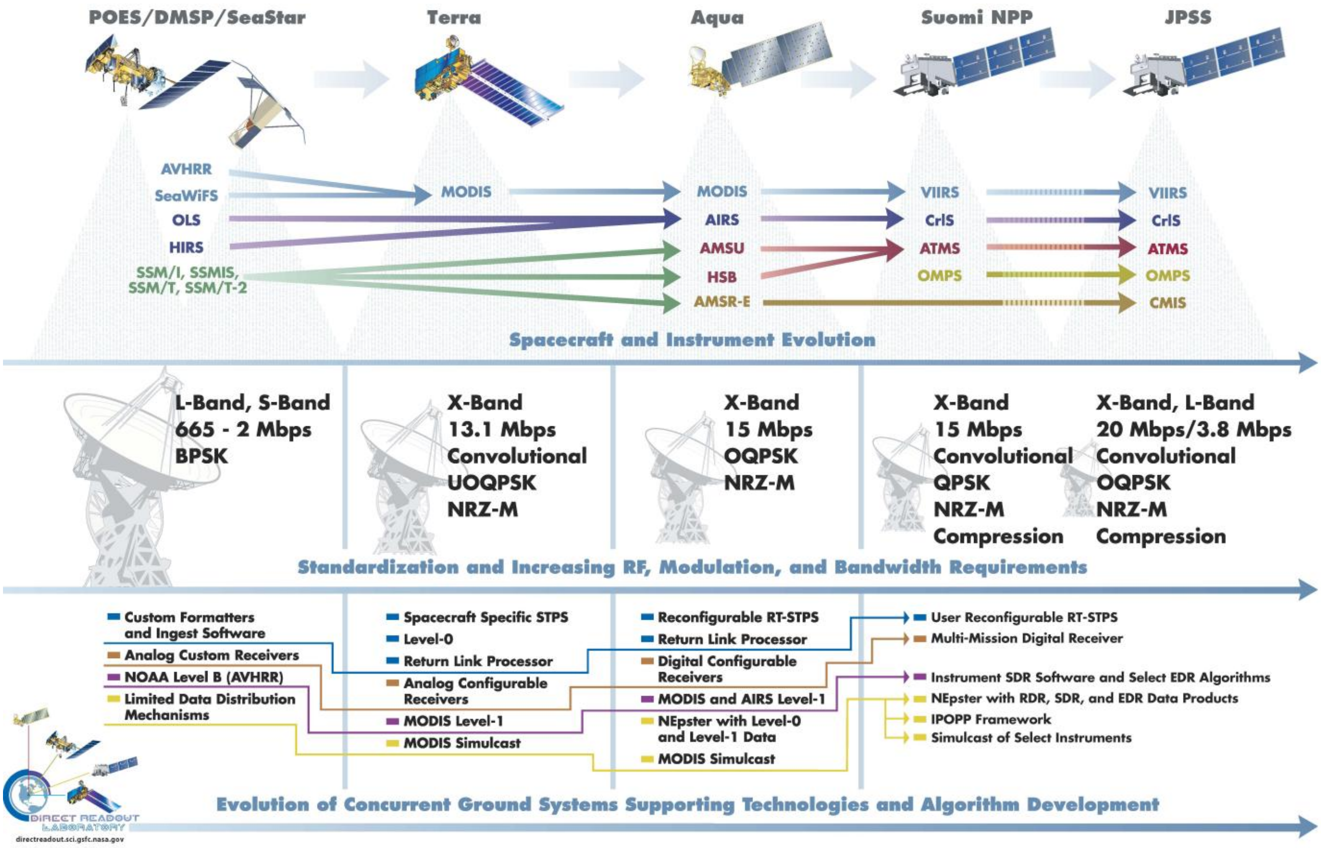

Figure 2.1 DR Technology Roadmap

2.2 International Polar-Orbit Processing Package (IPOPP)

The IPOPP is the primary element that addresses the technology needs to enable the real-time DR community to process, visualize, and evaluate EOS and S-NPP sensor data. IPOPP is available for download at: http://directreadout.sci.gsfc.nasa.gov/?id=software. The principle purpose of the IPOPP is to host Science Processing Algorithms (SPA), discussed in the next section. POPP system elements are illustrated in **Figure 2.2**.

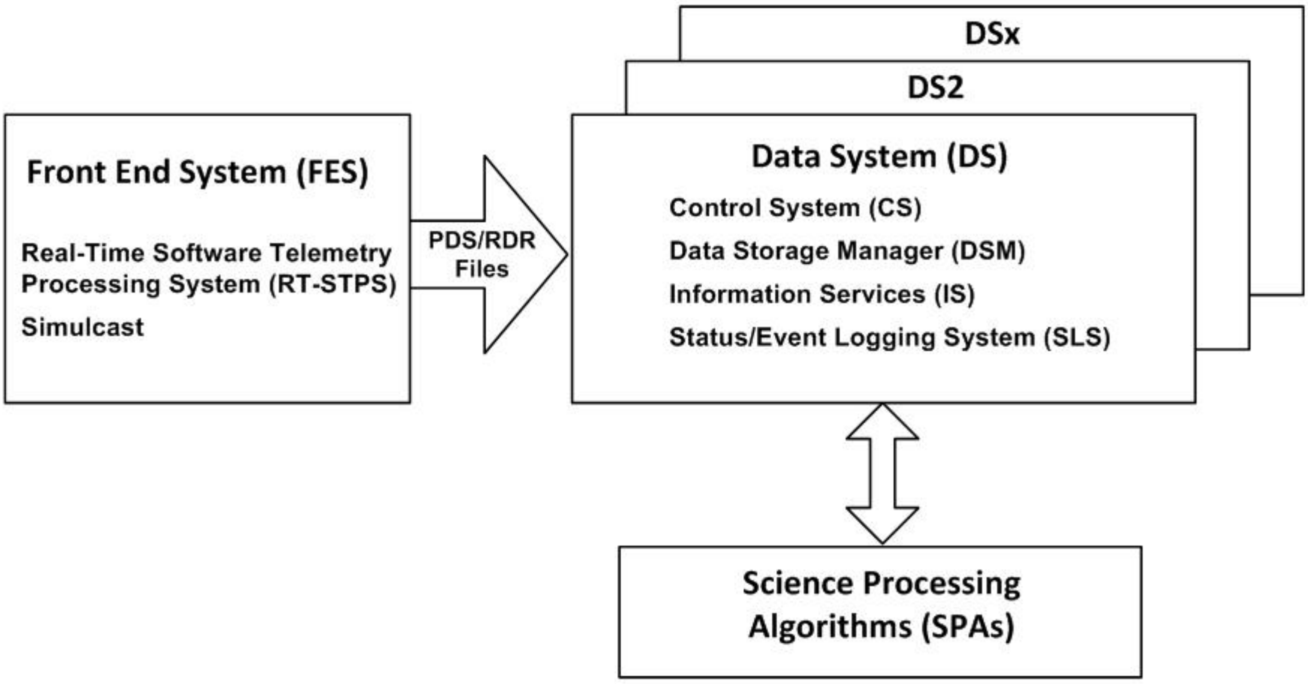

Figure 2.2 IPOPP Framework for real-time Earth science Data Processing

Beyond processing needs of the broader direct readout community, the IPOPP is used as a direct readout application's algorithm evaluation tool for collaborators. The generalized architecture is an excellent basis for algorithm evaluations; a heterogeneous implementation where the core resource management is verbose and easily referenced yielding ambiguity mitigation when performing detailed product intercomparisons.

2.1.3 NISGS Data System (NISDS) Control System (NCS)

At the heart of IPOPP is the NISGS Data System (NISDS) Control System (NCS). It is a standalone concept and is illustrated in **Figure 2.3**. The NCS is a Java-based DR technology that controls SPAs and thus product generation. NCS acts as the interface between the Data Storage Manager (DSM) and the Science Processing Algorithms (SPAs). The DSM maintains product storage. NCS retrieves SPA input products from the DSM, and creates the environment for execution of the SPA modules. Once NCS has executed an SPA, it registers the resulting output products with the DSM.

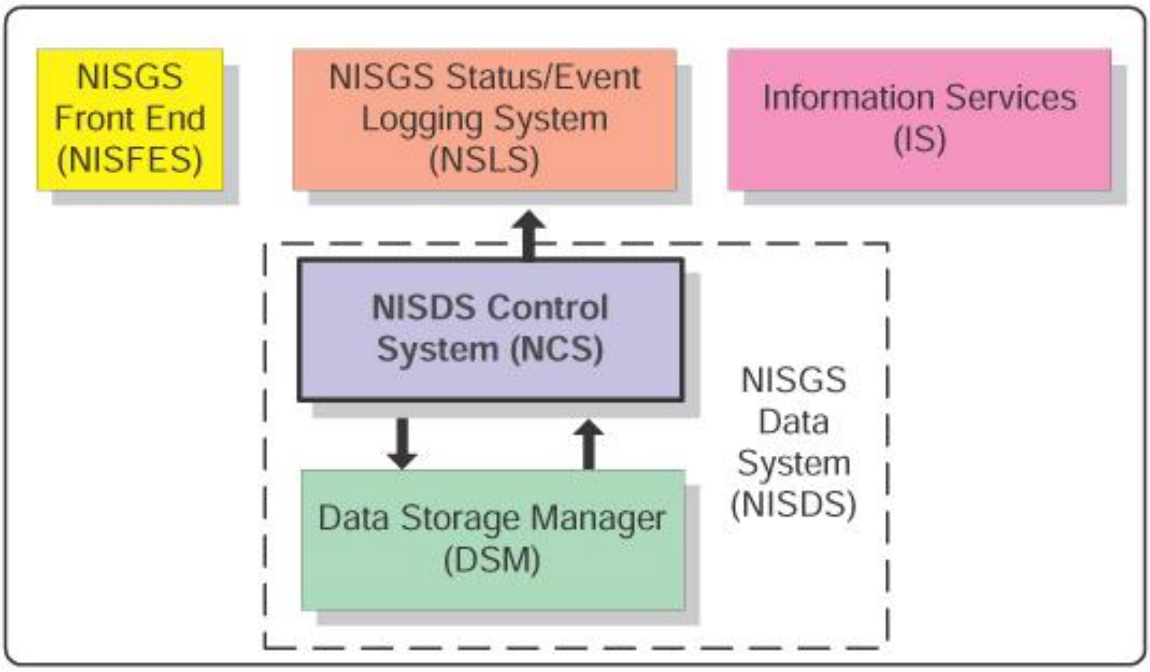

Figure 2.3 IPOPP Data System Architecture

The NCS architecture is decentralized and based on the notion of a station. Each station runs an SPA when the required resources are available. There may be any number of stations in the NCS, as depicted on **Figure 2.4**. The NCS is written in Java, and its design incorporates the following features:

- scalability, to accommodate indefinitely increasing processing loads;
- language-agnostic operations (i.e., SPA software may be written in any language);
- automatic execution of programs in proper order;
- product generation restart;
- easy addition of new SPAs;
- rapid fault isolation;
- platform-independence.

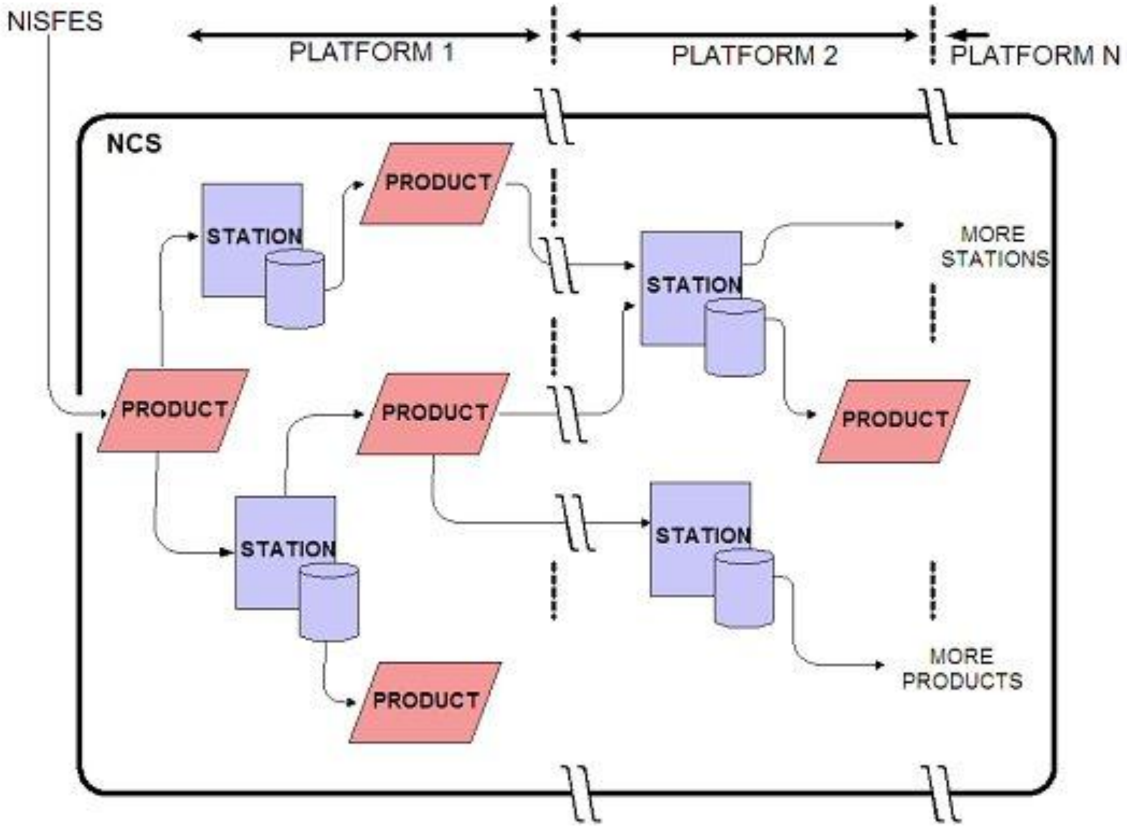

Figure 2.4 IPOPP Scalability and Distributed Architecture

The NCS contains any number of stations, each of which controls a SPA or other program. Each NCS station has a control program and a subdirectory.

The subdirectory contains a configuration file, and any other files or links required by the algorithm software. The configuration file is a keyword and parameter text file specifying values and actions to the control program. A lock file prevents multiple instances of the control program at the same NCS station. The control program instance for each station is identical, but the station's configuration file defines its unique algorithm control functional behavior.

2.1.2 Data Storage Manager (DSM)

The DSM is a standalone, Java-based DR technology that acts as a dynamic broker between the NISDS Control System (NCS), which creates output products according to SPAs, and Information Services (IS), where input products and ancillary data are stored.

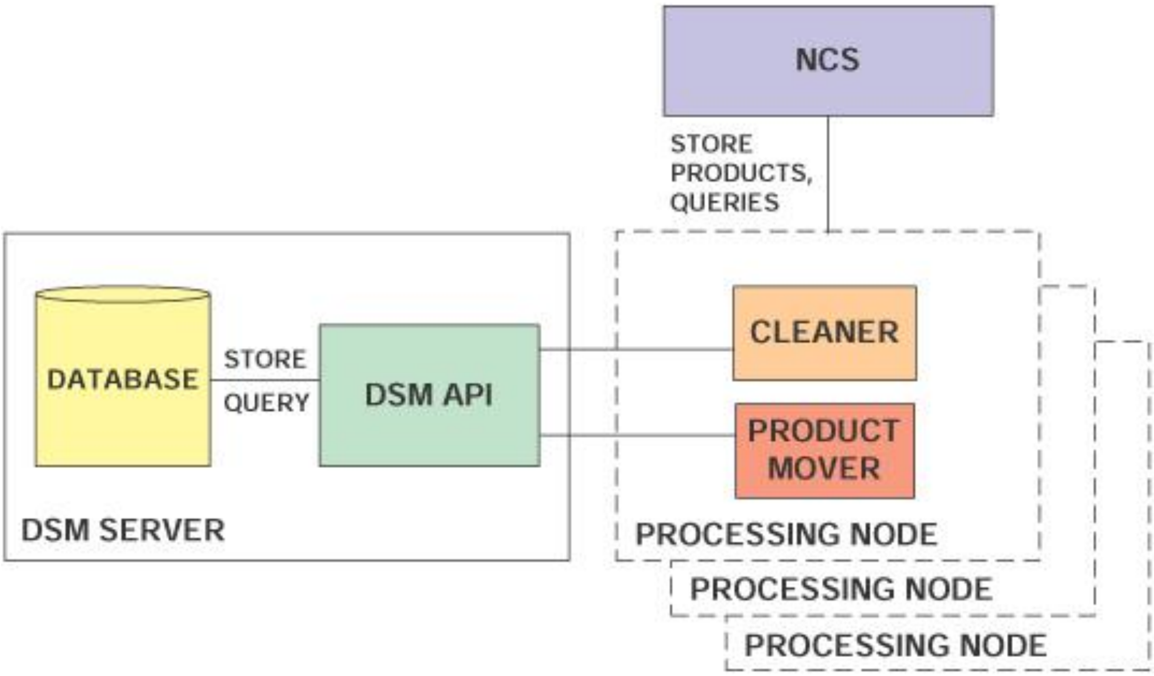

Figure 2.5 Data Storage Manager Architecture

The DSM consists of a database (preferably MySQL) that resides on one computer, an interface library, and a number of agents that perform other DSM functions, such as moving products and deleting obsolete products. The DSM architecture is depicted on **Figure 2.5**.

NISDS Control System (NCS) stations create the environment in which SPAs run and create output products. Each SPA requires a specific set of input products and ancillary files in order to generate its output product. When queried by the NCS stations, the DSM provides the locations of required input products and ancillary data, which reside within Information Services (IS).

In the Goddard Space Flight Center (GSFC) implementation – acting as a generic DR ground station – the Real-Time Software Telemetry Processing System (RT-STPS), **Section 2.3**, places Level 0 files into the "/data" directory on the NISGS Front End System (NISFES) computer. PdsMover, a mission-specific agent that moves data from the front end to the data processing element, reads the construction records of the Level 0 files. PdsMover then creates pass entries, gets product types, and creates product metadata, and places all of these things into the DSM database. PdsMover also publishes Level 0 products to Information Services.

The DSM Retriever (DSMR) retrieves Level 0 products, ancillary files and other resources from Information Services. DSMR provides all of these things to the NCS Station so that it may create a product. When an NCS Station has created a product, it notifies the DSM, and the Publisher agent publishes the completed product to Information Services. The product's location is stored in the DSM database.

2.1.3 Information Services (IS)

The Information Services (IS) subsystem is a Java-based data server technology that maintains a repository for storing and distributing data generated locally by a data processing system (such as the NISGS Data System [NISDS]), as well as auxiliary and ancillary files and end products. **Figure 2.6**.

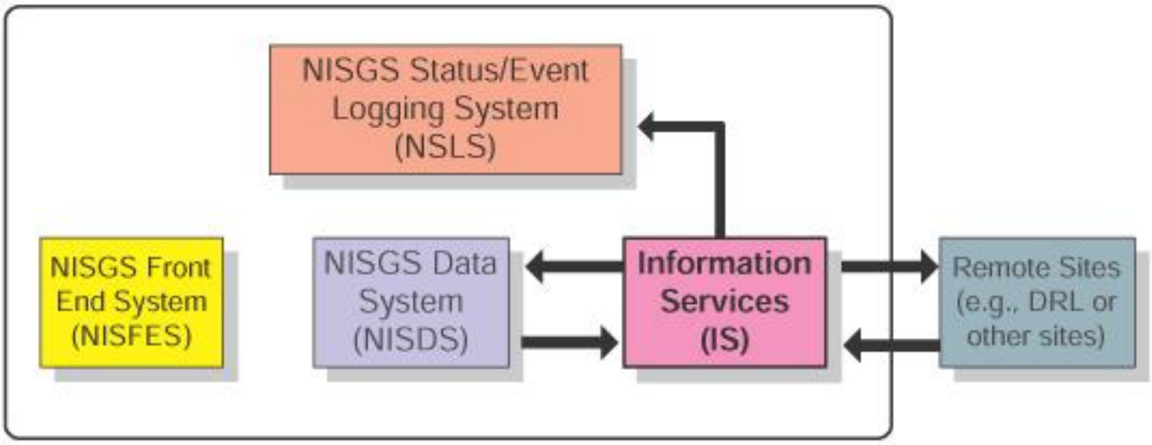

Figure 2.6 Information Services (IS) Architecture

The IS at Goddard Space Flight Center (GSFC) is configured to provide short-term special data services and fulfill auxiliary and ancillary data requirements that may be beneficial to the global Direct Broadcast (DB) community.

2.2 Science Processing Algorithm (SPA) Architecture

The SPA wrapper is key to the modular, real-time Earth data processing approach. Algorithm wrappers provide a common command and execution interface to encapsulate multi-discipline, multi-mission SPAs as described in **Figure 2.7**. The wrapper also provides a structured, standardized technique for packaging new or updated algorithms with minimal effort.

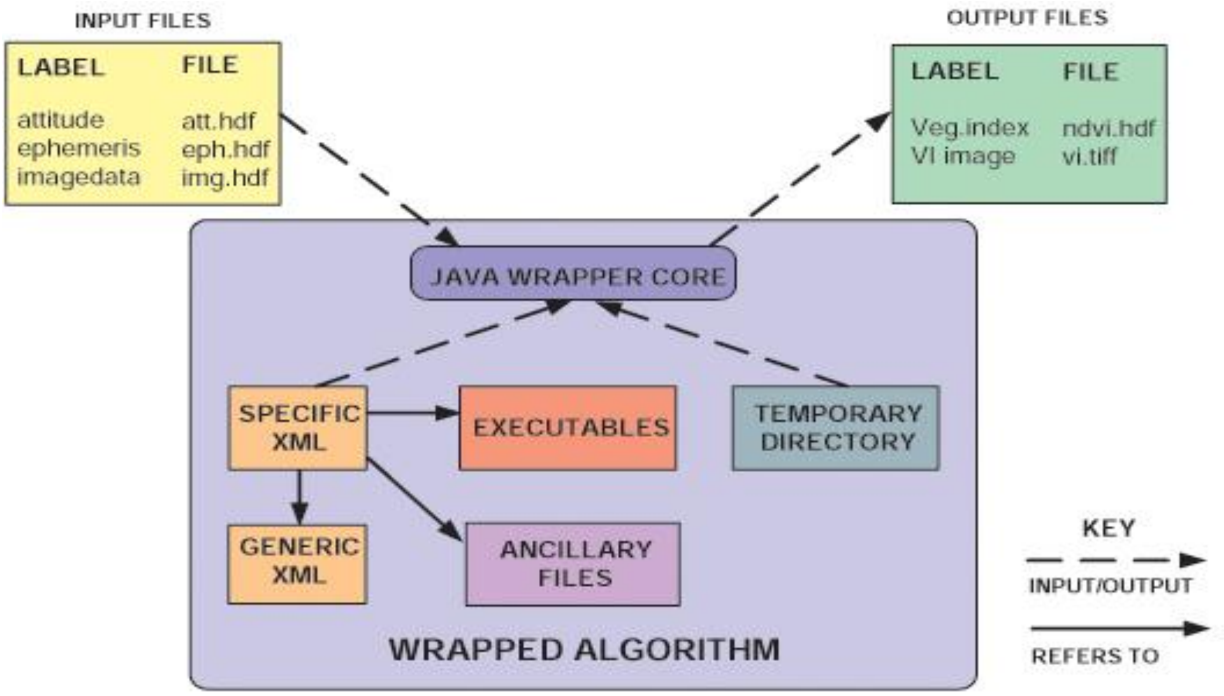

Figure 2.7 SPA Architecture

Figure 2.8 illustrates the SPA concept within IPOPP context. It shows the four functional components for a basic SPA: Core algorithm, a single Wrapper, a single Station and a single Ancillary Retriever. Complex SPAs may have multiple Stations, Wrappers or Ancillary Retrievers, but the basic relationship between these components and how they interface with each other remain the same.

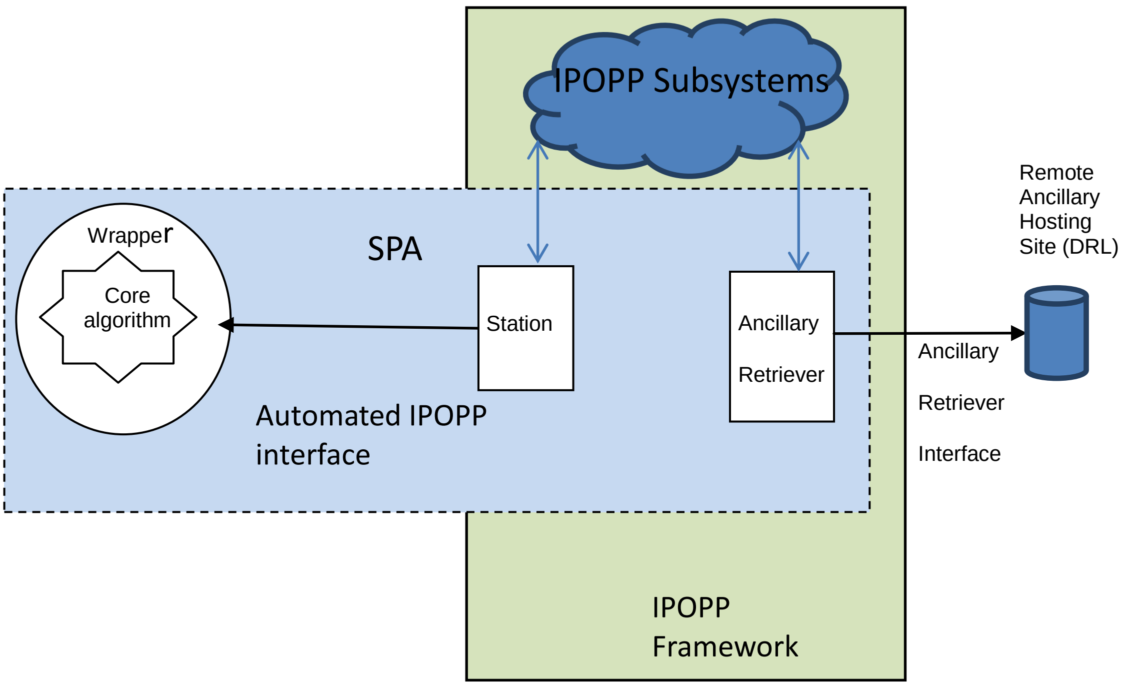

Figure 2.8 Science Processing Algorithm Architecture within IPOPP Implmentation

Core Algorithms: are obtained from various disparate groups and as such their command line interfaces are often very different from each other. Additionally, when using a Core Algorithm in its native form, an operator may have to perform various tasks to get the final results (e.g. setting environmental variables, running preprocessors, chaining different processes, etc.).

The Wrapper: standardizes the disparate algorithm interfaces and simplify what the operator needs to do to get things done. This interface standardization also enables the SPA to be plugged into IPOPP. The Wrapper interface is specified using wrapper labels. Wrapper Labels are simply predefined names for SPA inputs, outputs and flags. Each label must be followed by its actual value. In other words Wrapper Labels are variables that can be assigned values. The matching of the Wrapper Label to its corresponding value must be done either by the human operator or the Station. There are three types of <label value> pairs that the SPA can use, as follows:

a) Input file label/values. These are input file paths. Values are absolute or relative paths to the corresponding input file.
b) Parameter label/values. These are parameters or flags that need to be passed onto the SPA
c) Output file labels. These are output files that are produced by the SPA. Values are the relative/absolute paths of the files you want to generate.

In standalone mode, the operator simply specifies the <label value> pairs on the command line in order for the SPA to execute. To run an SPA in automated IPOPP mode, it has to be plugged into IPOPP. This plug-in is accomplished by executing an installation script. The installation script installs the SPA Station(s) and the Ancillary Retriever(s)into IPOPP and performs other tasks like registering product types and ancillary types. A product type is a handle for grouping similar products; for example, all TERRA MODIS LST products can be grouped under the product type 'drl.terra.modis.lst'. Similarly an ancillary type is a handle for grouping similar ancillaries; for example, all NCEP GDAS ancillary files can be grouped under the ancillary type 'drl.ncep_gdas_grib1'.

The Ancillary Retriever: Once installed into IPOPP, it starts retrieving ancillary files from remote ancillary hosting sites at a defined schedule. For all SPAs developed by the DRL, the ancillary hosting site is DRL's ancillary repository.

The Station provides the mechanism necessary for automated IPOPP processing. Conceptually, the Station performs all the tasks that a human operator would have done to run the algorithm in its Standalone mode. The Station queries IPOPP to find a set of input files (from the same satellite overpass) of particular product types and matches them to their corresponding wrapper labels. Similarly the station queries IPOPP to find ancillary input files that satisfy certain temporal criteria and matches them to the correct wrapper labels. The Wrapper labels corresponding to any algorithm flag are set by the station. The Station also sets the output file names and paths and matches them to their correct wrapper labels. Once the Wrapper labels have been initialized, the station invokes the Wrapper. The Wrapper executes the algorithm, producing outputs. The station then registers the outputs with IPOPP under the correct product types. Registering the outputs under the correct product types provides IPOPP with the information necessary to respond to product requests from a downstream SPA.

2.3 Real-Time Software Telemetry Processing System (RT-STPS)

From **Figure 2.9**, the RT-STPS is a front-end element into IPOPP. It ingests raw CCSDS-compliant data units that may be Pseudo-noise (PN)-encoded or Reed-Solomon (RS)-encoded and outputs Virtual Channel Data Units (VCDUs) or packets into the following formats:

- RDR files: Suomi NPP VIIRS, ATMS, CrIS, MODIS, AMSR-E, AIRS
- Production Data Set (PDS) (packet file and Construction Record [CSR]) file pairs;
- File: header, trailer and no annotation;
- Sockets.

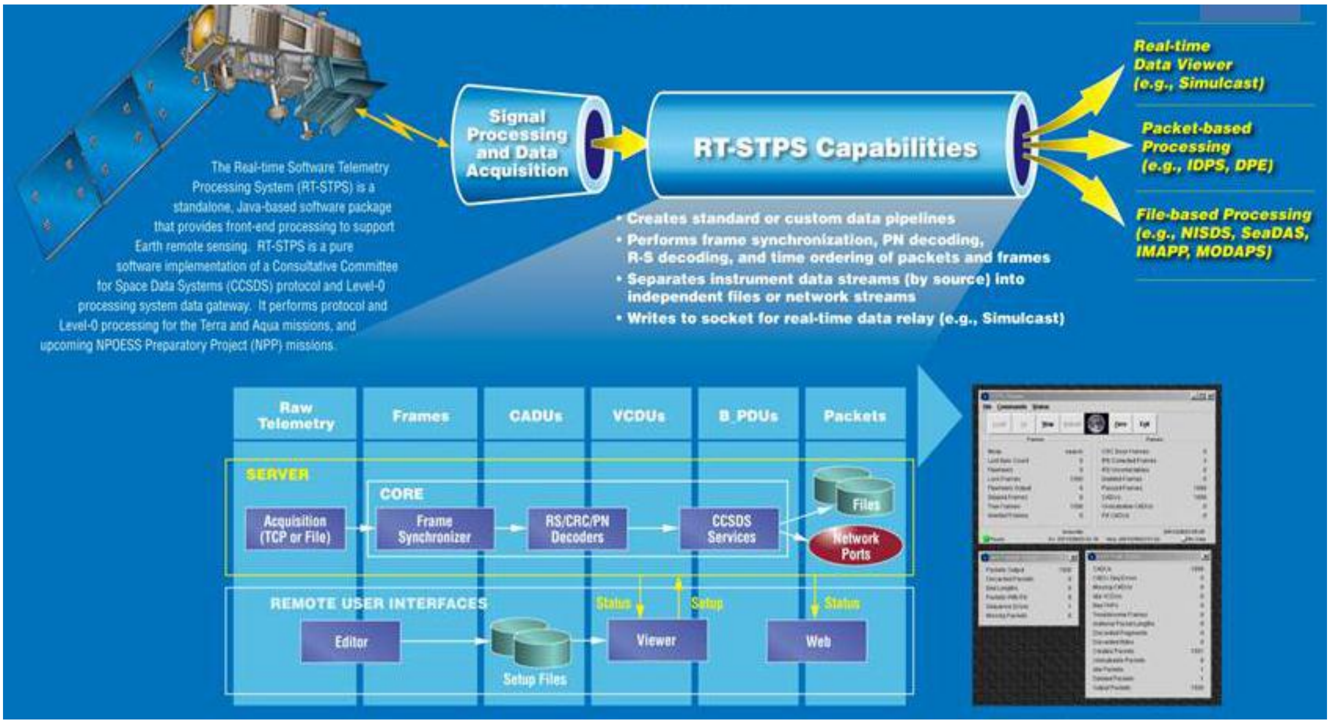

Figure 2.9 Real-Time Software Telemetry Processing System (RT-STPS) for Raw Data Packet Processing to Mission Format Standard and real-time data dissemination

RT-STPS functions in two modes: Standalone, or as an IPOPP plug-in. Installed as a server RT-STPS will operate continuously, receiving data from a port or a file and outputting results to files and sockets as specified in a configuration file. A separate interface can be used to invoke RT-STPS from the command line.

The RT-STPS package includes two main utilities: the viewer and the sender. The viewer displays the progress of the server as it runs, and it can be used to load server configuration files. The sender copies a raw data file to the server for processing. RT-STPS is available for download at : http://directreadout.sci.gsfc.nasa.gov/

2.4 Simulcast

Simulcast is a real-time Java application that allows users to select and view quicklook instrument data from multiple missions and spacecraft locally or remotely. Simulcast specifically addresses the need to view imagery in real-time no matter where the user is located so long as an internet connection of 128Kbps and above is available. Simulcast provides real-time geolocation and pseudo-calibration, and projects data on Mercator and Polar maps. Simulcast can replay recent satellite passes, export displayed images to JPEG format, and save replayed passes to AVI/Quicktime movies. Simulcast functions in two modes: Standalone, or as an IPOPP plug-in.

The Simulcast Client consists of the Simulcast Viewer and the Simulcast Console. The Viewer displays data from satellite passes (VIIRS data from S-NPP, and MODIS data from Aqua and Terra) as seen on **Figure 2.10**. The Console displays and controls administrative information. Before data can be displayed with the Viewer, the data must first be acquired, routed and processed by Simulcast Services. Simulcast Services contains the Simulcast Router, Processor and Server.

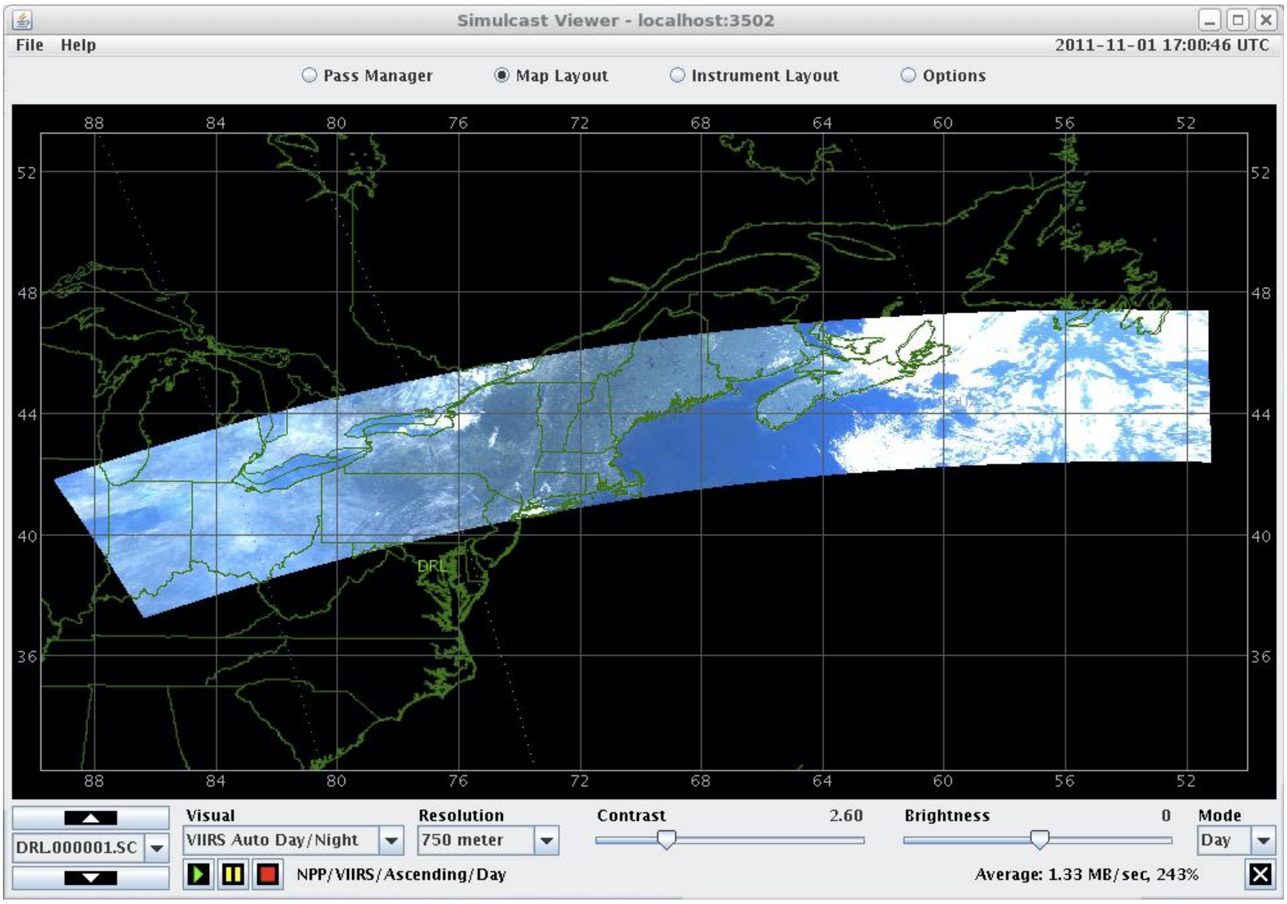

Figure 2.10 Simulcast Real-Time Viewer Interface

When a pass starts, the Router receives the CCSDS packet stream from the RT-STPS and transmits the packets to one or more Processors. The Router filters the packets by instrument type.

The Processor receives the filtered packets from the Router and extracts instrument data. The Processor calibrates the data, corrects the bow tie effect, and reduces data volume. The Processor transmits viewable data to the Server. The Server receives viewable data from the Processor and notifies Clients that the new pass data are available. The Server simultaneously stores the data locally (for possible replay later) and transmits it to Clients and other Servers, **Figure 2.11**. A Server can handle connections from multiple clients simultaneously, with each Client either receiving the data from the current pass or from a previous pass, **Figure 2.12.**

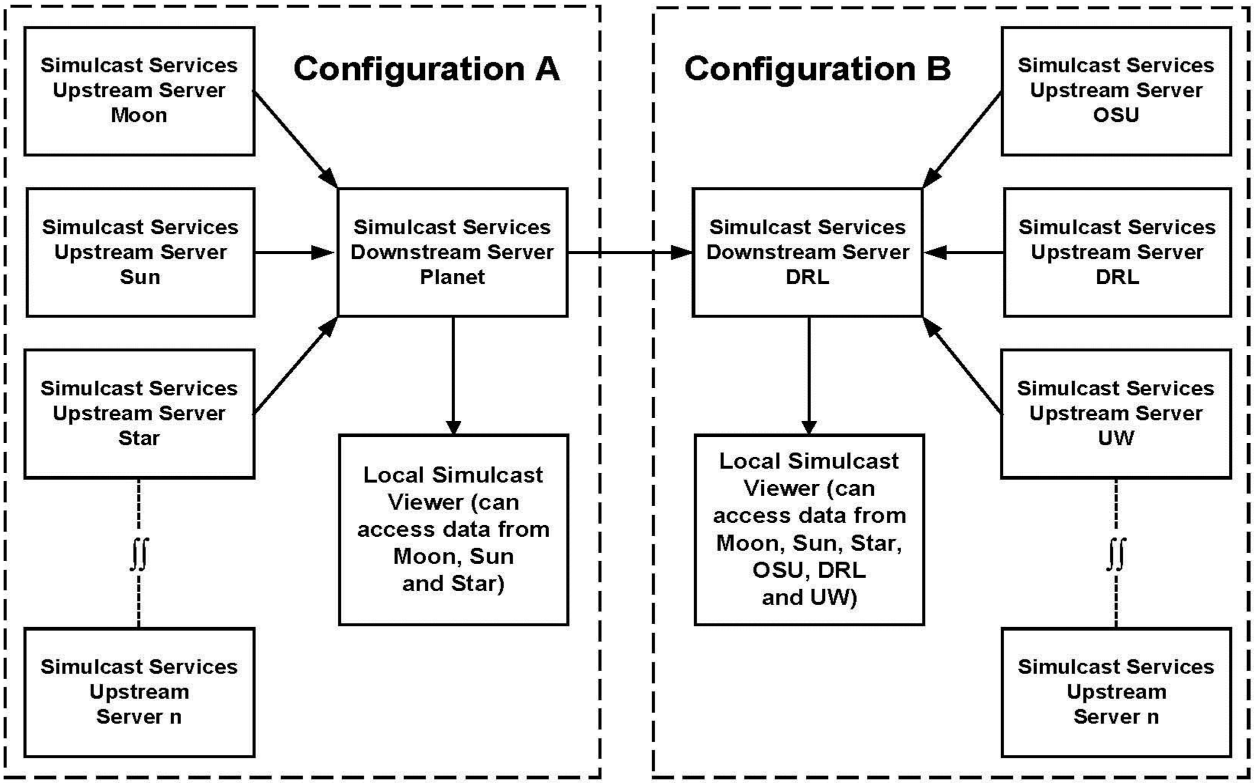

Figure 2.11 Simulcast Distributed Data Access Architecture

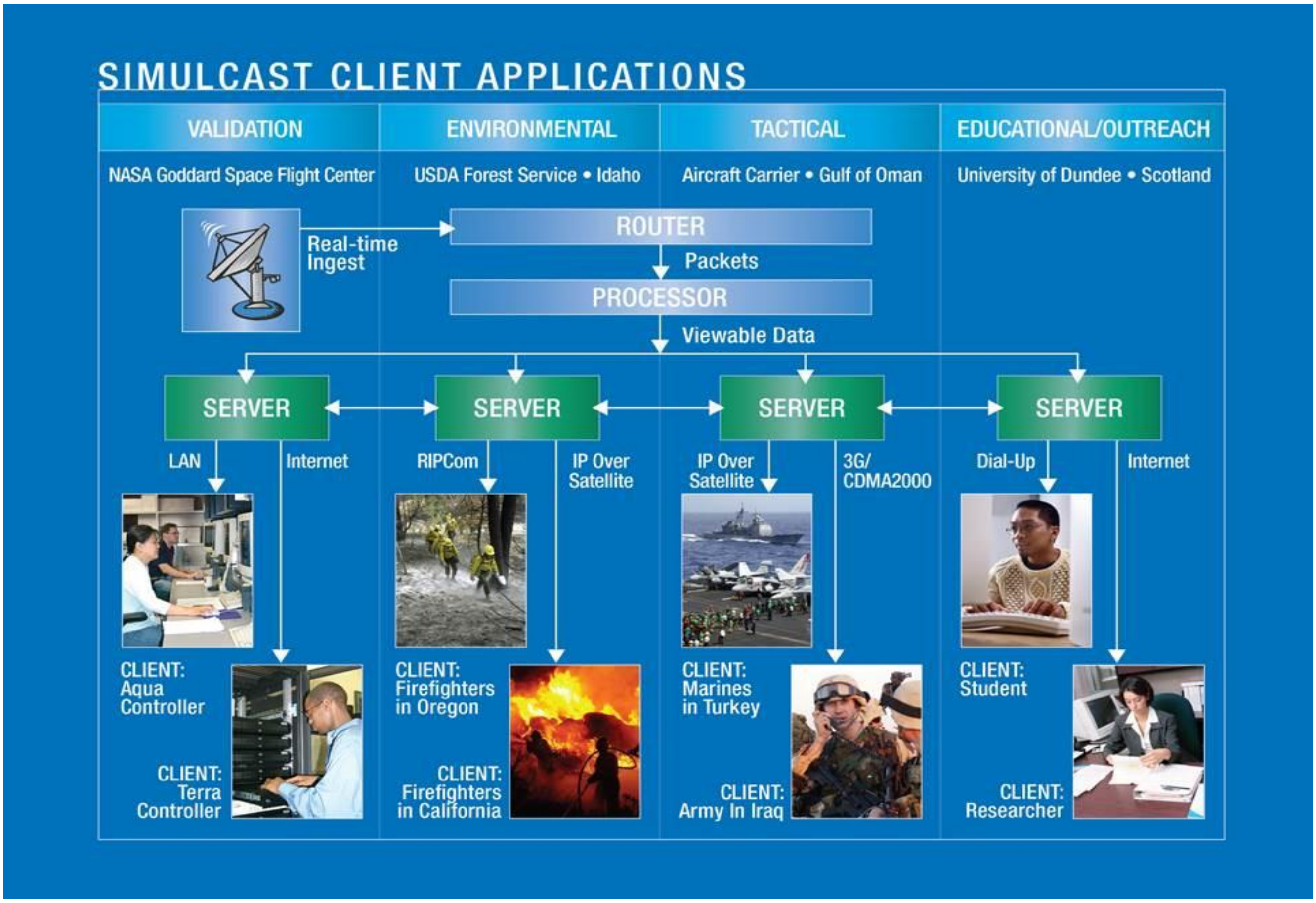

Figure 2.12 Simulcast Distributed Data Access Architecture in an Application Environment

3 APPLICATION SCIENCE ALGORITHMS

Once DB is made possible on the spacecraft or through an IP network, the second equally as important component of the overall concept of DB needs to be addressed, the application science algorithms. These provide, at a minimum, scientifically valid baseline products of geophysical parameters that can be of regional utility.

Within NASA's EOS missions, S-NPP and JPSS-1, significant efforts have been made to develop science products that would stand to the scrutiny of global change studies. These science algorithms are supported by extensive calibration and validation campaigns pre and post launch which have supported the now continuous update to these algorithms and enable accurate data and sensor continuity measurements.

The most important algorithms for the direct readout community have been for their use with the MODIS instrument on two EOS spacecraft (Terra and Aqua). This instrument, with its support science algorithms, provides geophysical parameters that are of high utility to the global community. But with any science quality algorithm there has to be a process by which to validate the ported, wrapped algorithm that is to be used in a direct readout environment. The porting process is necessary and is defined as the process of making necessary environmental algorithm changes/additions so as to allow such algorithm to function in a direct readout environment, where system infrastructure-based dependencies are removed and/or emulated, variable data blocks is the norm, and variable ancillary/auxillary data sources and conversions may exist. Once porting is complete the algorithm is supported by the SPA wrapper which provides a run-time interface standard and all the hooks and functions necessary for the direct readout user to incorporate such SPA into their existing processing chain or the IPOPP.

Currently available MODIS instrument SPAs through the NASA's Direct Readout web portal are listed below: http://directreadout.sci.gsfc.nasa.gov/?id=software

- Fire Detection – MOD 14
- Vegetation Index
- Enhanced Vegetation Index
- Vegetation Fraction
- Surface Albedo
- Surface Reflectance
- Sea Surface Temperature (SST)
- Sea Ice (SST)
- Snow Cover
- Chlorophyll-a Concentration
- Cloud Mask
- Suspended Matter
- Cloud Optical Thickness
- CloudTop Pressure
- Cloud Top Temperature
- Aerosol
- Aerosol Particle Size
- Effective Particle Size
- Cloud Top Properties and Cloud Phase
- Atmospheric Profiles
- Water Vapor
- Land Surface Temperature (LST)
- Corrected Reflectance (CREFL)
- True Color
- Level 1

Currently available VIIRS, ATMS and CrIS instrument SPAs:

- VIIRS RDR and SDR
- Aerosol Optical Thickness (AOT)
- Cloud Base Height
- Cloud Effective Particle Size
- Cloud Optical Thickness
- Cloud Top Height
- Cloud Top Pressure
- Cloud Top Temperature
- Ice Surface Temperature
- Imagery Band I1 – I5
- Imagery Band M1-M16
- Land Surface Temperature
- Near Constant Contrast Imagery
- Sea Ice Characterization
- Surface Albedo
- Suspended Matter
- Vegetation Index
- CrIS CRIMS RDR, SDR and EDR
- ATMS SDR, RDR

3.1 SPA Verification

Prior to the release of an SPA, a rigorous verification process is undergone to ensure that the output product is scientifically valid and comparable to the equivalent institutional global algorithm product. This process, an example of which is described in **Figure 3.1**, ensures that science quality is maintained and forms a reference for any enhancements undertaken by the end user. The latest SPAs, or product algorithms are freely downloadable from the DR web portal at http://directreadout.sci.gsfc.nasa.gov/?id=software

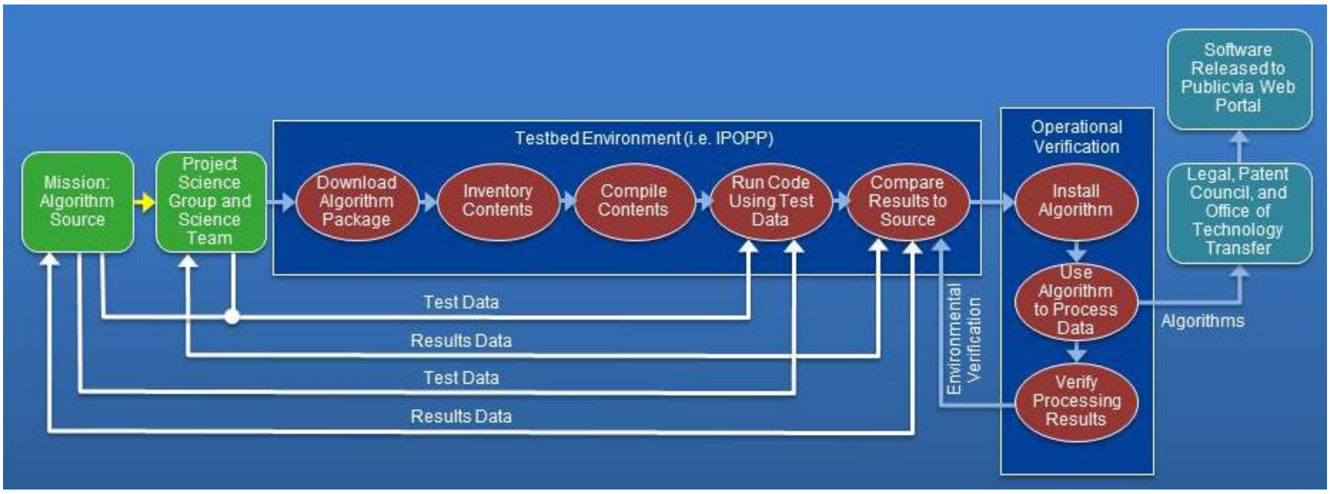

Figure 3.1 SPA - Standalone Science Processing Algorithms and Product Verification for Direct Readout Environment

Modifications to an SPA by direct readout users to suit local conditions and environmental variability is on the rise. Local users possess significant leverage on the utility of an SPA based on local access to in-situ data. Enhancements and/or changes to the SPA can come in the form of adjustments to the input calibration tables at the Science Data Record (SDR or Level 1) level and/or the provision of finer resolution ancillary data sets. Additional types of modifications include data-type filters, such as local information on soil and vegetation type that requires reflectance adjustment or measurement exclusion. Regardless of the changes made, direct readout data users rely on the “reference” global product generated by the original SPA and/or by the corresponding NASA-DAAC or LANCE provided product to ensure product quality continuity.

In the direct readout community regional products can be different when compared to the” reference” global product. In these cases a trade-off is made initially between the algorithm reduction in science quality and availability of the algorithm. An example of this is depicted in the Normalized Difference Vegetation Index (NDVI) product in **Figure 3.2**.

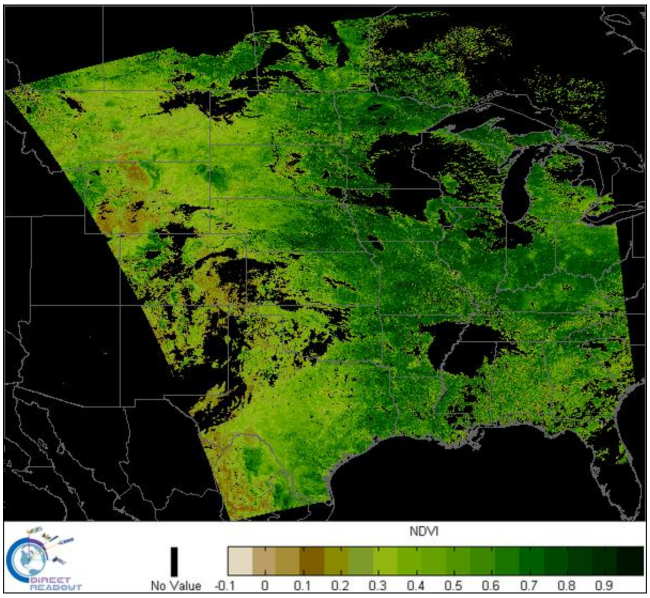

Figure 3.2 Direct Readout Normalized Difference Vegetation Index (NDVI)

The reference global NDVI product is a 16-day composite product where the BRDF artifacts are reduced by the compositing process. In the SPA form, NDVI does not afford this process and generates a product every orbital pass. Nevertheless, these examples are few, and all direct readout users equipped with this information have made enhancements to the SPA to better suit their near-real-time needs.

4 HAZARDS MANAGEMENT AND MITIGATION

Environmental monitoring using DB from polar-orbiting satellites has become common place world-wide. There is an element of time criticality that is inherent in DB or network-based data/product access, such as NASA LANCE; it has shown to save lives and property by providing meteorological agencies with improved warnings of severe weather, especially tropical cyclones. The use of DB and/or near-real-time network-based data in hazards monitoring and mitigation has legacy with the MODIS instrument which has been designed to extend the environmental observing capabilities of the Advanced Very High Resolution Radiometer (AVHRR) on NOAA operational satellites.

Over the last decade science algorithms have been playing an increasing role in real-time applications such as in hazards monitoring, man-made or other. From **Figure 4.1 and 4.3**, one can see the obvious uses of the DB MODIS instrument data which are enhancement to existing SPAs. Additional utility has been given to these products by augmenting the image product with GIS information layers and encompassing them in an image transport mechanism as described in the next section. Direct readout users have also made use of individual spectral MODIS bands to generate their own products such as depicted in **Figure 4.2** with the sand storm tracking product.

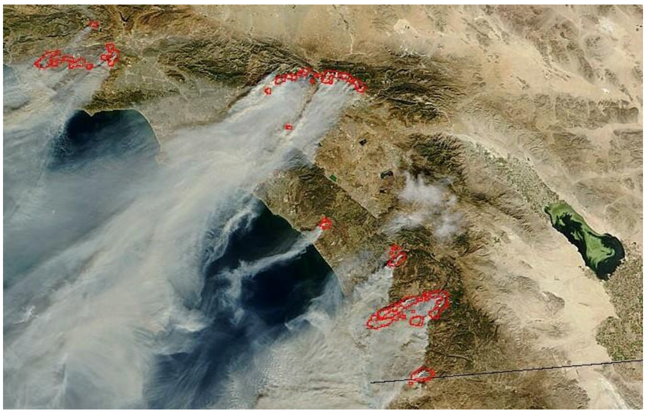

Figure 4.1 Fire Mapping with Hot Spots Overlay

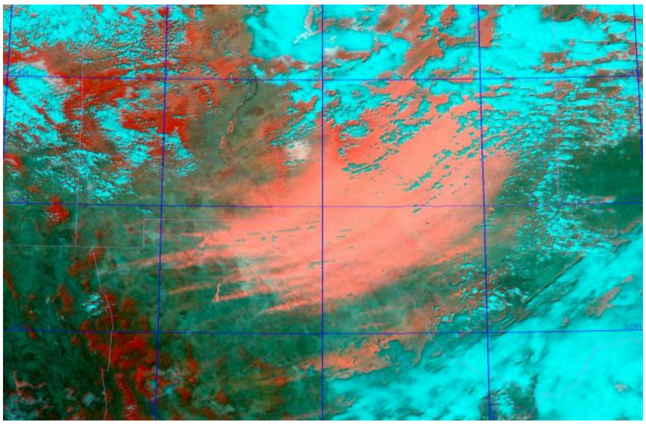

Figure 4.2 Sand Storm tracking

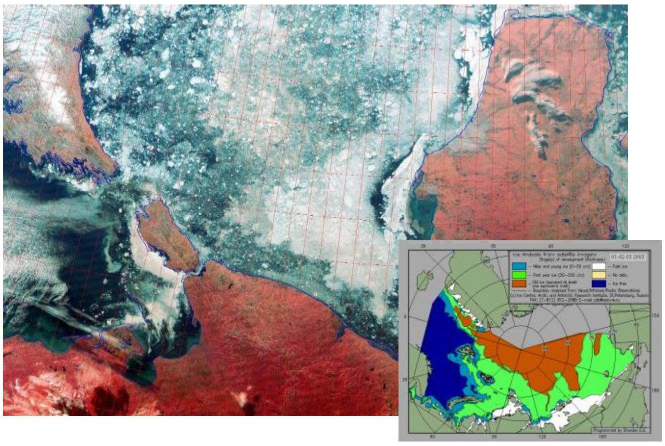

Figure 4.3 Sea Ice Monitoring on Shipping Lanes

The SPAs for these products are available for download at http://directreadout.sci.gsfc.nasa.gov/?id=software and are continuously updated based on instrument changes, algorithm improvements and calibration table updates. For forecast and nowcast, additional applications examples from users include the US National Weather Service is using MODIS and AMSR-E Level-1 DB imagery through NASA's Short-Term Prediction Research and Transition Program (SPORT) in support of forecast validation and nowcasting. In other disciplines many nations are using polar-orbiting DB data for fish location and inventory forecasting, mosquito population and Malaria potential, flood prediction and typhoon track predictions.

5 PRODUCT TRANSPORT MECHANISM

Most real-time applications make use of a geographic information system (GIS) that brings together various pieces of information and presents them in a way that allows for the user to accurately gauge environmental impact. These assessments are critical in the decision-making process. In this process, product transport mechanism must become ubiquitous if they are to be depended upon. The EOS, S-NPP and eventually JPSS-1 missions have produced tremendous amount of data in HDF-EOS and HDF-5 formats, which unfortunately cannot be imported in a useful, semi-autonomous manner into most contemporary GIS systems. However GIS remains one of the most important tools for analyzing NASA's EOS data and promoting real-time applications. GeoTIFF is one of the GIS-ingestible formats and therefore the ability to produce GeoTIFF from HDF-EOS and HDF-5, will greatly enhance the interoperability and public use of EOS/JPSS data. The availability of GIS-ready products will improve data analysis and visualization, promote the use of such data not only in global change research but also in the public who is concerned with issues such as environment and resource management, hazard mitigation, education, and community planning.

A primary step in making this happen is to enrich the GeoTIFF format with the necessary metadata. Geospatial metadata have been recognized for playing four roles: (i) Availability: metadata needed to determine the sets of data that exist for a geographic location. (ii) Fitness for use: metadata needed to understand how the data was acquired and processed (lineage) to determine if a set of data meets a specific need (iii) Access: metadata needed to acquire an identified set of data and (iv) Transfer: Metadata needed to process and use a set of data. Apart from these four obvious uses, metadata can be an important component in triggering future research and development by means of a feedback mechanism. As users analyze the lineage metadata associated with a dataset, they may identify processes that may have degraded the data quality and discover alternate techniques that could potentially improve the data quality and make it suitable for a particular application.

As a prime example of metadata enhancement is the incorporation of standard color tables within the GeoTIFF meta-data fields. Such tables would be helpful in promoting uniformity in visualizations of a particular Geophysical parameter. Over the years researchers have associated each EOS product with a color map that best represents the parameter described in the product. The color map used for the NDVI product in **Figure 3.2,** for example, is thus different from the color map used for the ocean color product, which typically uses a log scale color map. This implies that it would be beneficial for the user community if the standard color map is encoded within the GeoTIFF product. This would ensure that the user has access to the standard color scale used for the product. The user however will have the flexibility to change the color scale within the GIS platform for further analysis. When producing GeoTIFF products we must ensure that the encoded color map is the standard color map representative of the geophysical parameter.

Geolocation and quality flag information would also form part of this ubiquitous product transport mechanism, and its validation would go through the same science validation process as described above and in **Figure 3.1**.

5.1 HDF to GeoTIFF (H2G_SPA)

In order to address the required GeoTIFF meta-data enhancements NASA has developed and is making available the H2G_SPA (Hierarchical Data Format [HDF] to Georeferenced Tagged Image File Format [GeoTIFF] Converter Science Processing Algorithm). H2G_SPA is specially designed for near-real-time processing and create geolocated GeoTIFF images, jpeg browse images, and png browse images for various parameter datasets in S-NPP SPA and MODIS Level 2 SPA products. H2G also creates standard true color images and user-defined false color images from supported VIIRS and MODIS science products. The H2G_SPA functions in two modes: Standalone, or as an IPOPP plug-in.

The geolocated GeoTIFF images are GIS-ingestible and can also be opened by standard image viewers. The non-geolocated jpeg and png images are more suitable as browse images. These browse images are enhanced with vector overlays of land/sea and political boundaries.

H2G_SPA incorporates the following features to enhance output images and facilitate scientific interpretation:

- while creating images from a primary dataset, a secondary dataset may be used to mask appropriate areas;
- user-defined color map and user-defined scaling capabilities for conversion of dataset values into image pixels;
- choice of either geographic or stereographic projection for the output image;
- optional subsetting of swaths into user-defined regions of interest;
- optional mosaicing of multiple swaths;
- jpeg and png browse images with legends;
- fire pixel overlays on other imagery (e.g., fire pixel overlays on TrueColor image).

H2G currently allows the user to select geographic and stereographic projections. Inclusion of other projections is under consideration for future releases of H2G_SPA.

The H2G_SPA stereographic projection capability utilizes the JPROJ.4 Java Native Interface (JNI) to the PROJ.4 Cartographic Projections Library. This library was initially developed by the U.S. Geological Survey (USGS) and is currently being maintained/enhanced by the Open Source Geospatial Foundation (OSGeo). Enhancements to H2G Version 2.3 available for download at http://directreadout.sci.gsfc.nasa.gov/ include:

- addition of documentation and test script support for SNPP VIIRS EDR products;
- extended support for VIIRS Ocean Color and SST science products;
- extended support for OMPS SO2, Aerosol Index, Ozone and Reflectivity science products;
- ability to generate imagery from Daily composite products (like the Level 2G products produced by the MODIS and VIIRS Burnscar SPAs);

- ability to generate a high resolution VIIRS True Color image product using the VIIRS I1 Band;
- ability to support global mosaiced image products.

6 SUMMARY

The ultimate goal of the direct broadcast or network-based remote sensing data user is to arrive at an understanding of its regional environment dynamics and derive information for decision support. Therefore the extent of DB's utility is directly proportional to the ability of the user to provide the derived information to a decision-making infrastructure; whether it is a large farmer assessing a fungal infestation or the federal government assessing damage extent of a tornado. Both require a mechanism or path for real-time DB products to reach appropriate decision-making bodies.

NASA, as a science research organization, has developed space-borne remote sensing instruments and corresponding science algorithms to measure and quantify geophysical parameters for use in understanding and quantifying climate change. Many of these algorithms, although for use on a global and longer temporal scale, are applicable for real-time regional applications. The Direct Readout program, in order to bridge the gap between NASA science and the end- user application, has developed support technologies and ported science algorithms, as described, to function in a Direct Readout environment for direct use by such application users. These are freely available for download at http://directreadout.sci.gsfc.nasa.gov.