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Introduction

The direct readout (DR) development at NASA Goddard is embodied in the prototype of the NPOESS Preparatory Project (NPP) In-Situ terminal Ground System (NISGS). This development has focused all DR technologies that are required to acquire and process data through radiometric calibration and geo-registration, and distribute all instruments of the next generation remote sensing satellites. The technology roadmap to make this possible is described in Figure 1.

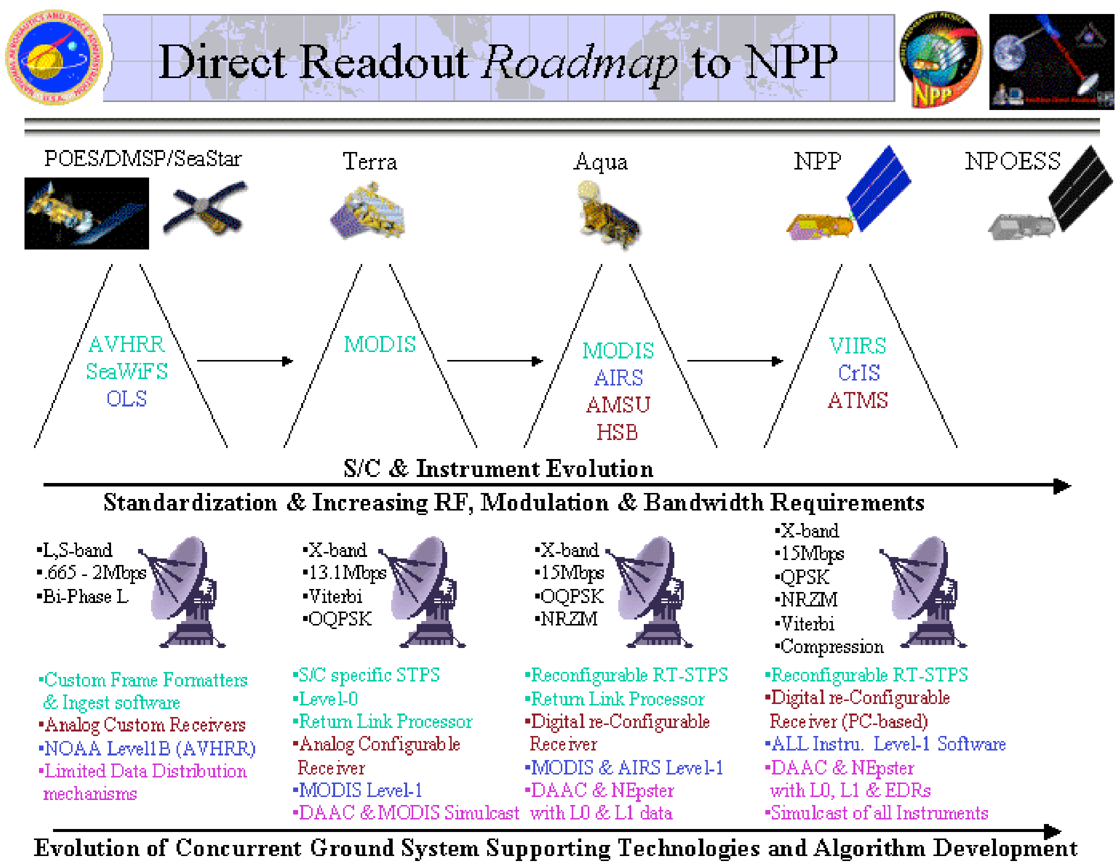


Figure 1.

The NISGS model encompasses subsystems that 1) perform CCSDS protocol processing and Level-0 formatting; 2) broadcast data on the internet, which distributes quick-look instrument data to internet-based clients in near real-time; 3) provide a web portal that serves as a virtually connected network of data archive systems providing access to direct broadcast data to anyone with a web browser; and 4) include Direct Broadcast/Institutional science processing algorithms, which run in either a near real-time direct-broadcast mode, or an after-the-fact research mode.

The NISGS technologies target most of the necessary steps prior to value-added image product generation. They also incorporate all instrument and spacecraft-specific formatting, encoding and configurations, thereby alleviating the end-user of this resource consuming task and development. The science processing algorithms process Level 0 data to geo-located, calibrated, radiances from which a number of geophysical value-added products can be generated. All of these sub-systems function standalone and can be easily implemented into any In-Situ ground terminal.

The NISGS model is also not specific to the remote sensing platform, in this case spacecraft. It can also acquire and process UAV data in real-time for immediate geo-registration and calibration for subsequent data fusion with other data sources of the same geophysical area.

NISGS Components and Data Flow

To better explain the data flow and processing, the NISGS is separated into the Front-End System (NISFES) and Science Data System (NISDS). The are further sub-sectioned into lower-level design elements. The NISFES consists of 1) Control/Scheduler Software, 2) Signal Processing, 3) Protocol Processing, and 4) Level 0 Data Generation. The NISDS consists of 1) Control Software, 2) instrument-specific Level-1 data generation, and 3) product specific algorithms (by instrument) that are used for data verification. At each step of data product generation, the data is archived and will be made available to the DB Community via another NISGS architectural element.

1) NISFES Automatic Scheduler and Controller Software: Provides orbital modeling and pass scheduling, enables and disables all NISFES components, and provides configuration to all NISFES components. Interfaces to NISDS control Software.

2) NISFES Processing Elements:
    a. Signal Processing: Provides RF processing to Baseband NRZ-L.
    b. Protocol Processing: Accepts asynchronous bitstream input from Signal Processing, frame synchronizes, decodes (PN and/or RS), sorts and filters frames based on VCID.
    c. Level 0 Data Production: Accepts frame input from Protocol Processing. Extracts packets from frames and generates time ordered packets for archive (file) or output to socket.

3) NISDS Control Software: Controls and configures NISDS components. Interfaces to NISFES control software.

4) NISDS Processing Elements:
    a. Instrument Specific Level 1 Data
    b. Product-Specific Algorithms by Instrument

The Near Real-Time Data Quality Monitoring, Web Portal, and Data Management and Distribution Subsystems all interface to the DB community. These three subsystems provide the community access to the NISGS output. The Data Management and

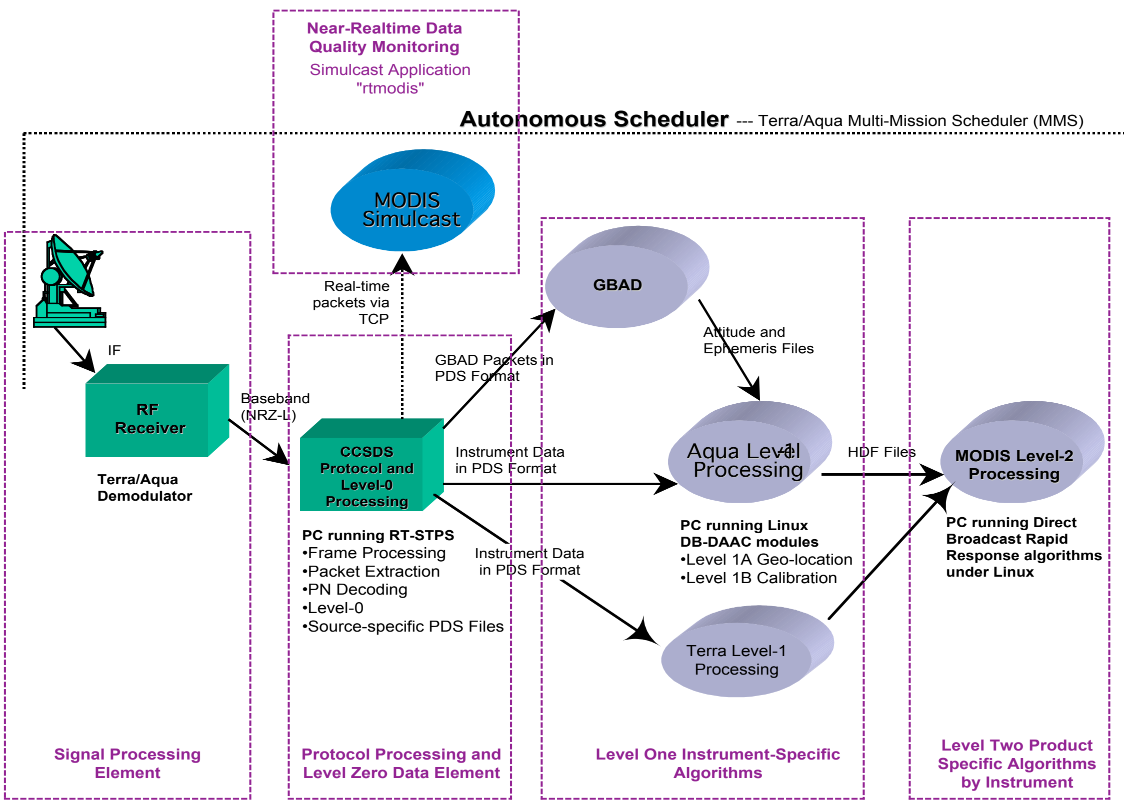
Distribution subsystem gives the DB community access to global data products, which include the NISGS outputs.

The key technology components of the Direct Readout System are listed and overviewed as follows:

- Multi-Mission Scheduler (MMS): Pass Scheduling and component control for Terra/Aqua Missions.
- Real-Time Software Telemetry Processing System (RT-STPS): CCSDS Protocol and Level Zero processing.
- Real-Time MODIS (Rtmodis): MODIS Simulcast program that broadcasts quick look images via a socket connection.
- GBAD: For Aqua, generates attitude and elevation ancillary data that is required input for Aqua Level-1 Processing.
- Aqua Level-1 Processing: DB-DAAC Modules that process Aqua data.
- Terra Level-1 Processing: DB-DAAC Modules that process Terra data.

Figure 2 presents the components and data flow of the Direct Readout System. The diagram also maps each component to the corresponding NISGS subsystem for which it provides baseline technology.

Direct Readout System: Baseline Technology for NISFES, NISDS, and Near-Real-Time Data Quality Monitoring Subsystems



Uninhabited Aerial Vehicles (UAVs)

The use of uninhabited aerial vehicles (UAVs) to carryout hyperspectral image data collection is a technically feasible solution to high temporal and spectral earth remote sensing.

The primary purpose of UAV's within the direct readout concept is to assess the feasibility and utilization of a hyperspectral imaging system on an unmanned aerial vehicle for high rate, real-time data access and distribution to a mobile end-user. In order to carryout this goal it is necessary to provide a test-bed environment for UAV direct readout technologies which can enable high rate data acquisition, processing and near real-time distribution of Earth Science remotely sensed data. In addition, in the process of assessing utility it is necessary to carryout this assessment within the context of supporting real-time spacecraft/instrument calibration and validation field campaigns.

Remote sensing is the primary feasible way of studying regional and global environmental processes and conditions. In addition to calibrating and determining the accuracy of remote sensing measurements, it is vital to the process of producing useful products from these measurements. Thus, validating remote sensing measurements is critical to their acceptance for solving real problems. This validation or ground truthing is an absolute necessity for the widespread application of remote sensing. To date, field ground truth surveys (the preferred validation technique) have been costly, time consuming and have very limited areas. Recent advances in instrument cost and design have made aerial measurement an acceptable method of extending ground truth survey results, however, these are also generally cost-prohibitive if data is required often to cover rapidly changing conditions. Thus there is a natural niche for a system outlined in this paper, which could:

- Provide greater frequency of ground truth surveys.
- Extend the area of the surveys.
- Respond to both scheduled and rapid reaction requirements.

A need for the capability to provide extended ground truthing, repeat coverage for environmental monitoring, rapid response time, flexibility of operating performance and ease of payload integration have been pronounced and well defined for many research and commercial applications.

In order to carry out many of these remote sensing missions over the national air space and people, intelligent systems must exist on board to ensure proper data acquisition and flight execution. Therefore acquiring hyperspectral image data and relaying it back to NISGS for immediate data processing will require high bandwidth digital communication system and flight navigation intelligence.

Direct Broadcast Data Communication System

For the data communication component, a system has been developed called Remote Internet Protocol Communication (RIPCom) system, which is a wireless communication system that makes an Unmanned Aerial Vehicle (UAV) look like a network node in the sky. RIPCom provides an Ethernet to Radio Frequency (RF) connection solution for real-time data transmission, and its design allows the end points of the communication system to become nodes on a network with assigned IP addresses. RIPCom's design is especially suitable for UAV applications, and its versatility makes it valuable for many systems that require a high speed, digital wireless network.

With the RIPCom System, end points of the communication system are nodes on a network. The result is that the RIPCom system greatly simplifies the development of payload systems by eliminating the need for specialized serial communications programs. RIPCom also provides faster bandwidth and quicker data access than historical serial communication systems.

The required Ground Station application was unique and presented many integration issues that resulted in technology development. While the aircraft was a fairly straightforward use of COTS equipment, the Ground Station design process had to undergo several iterations. For example, reassociation and phase distortion issues influenced the final configuration of the RIPCom implementation.

RIPCom Ground Station design began with analysis of the standard implementation of the chosen antenna. A typical design is to use one DS.11 radio for each input of the 3-sector antenna. Therefore, version one design of RIPCom included three Base Unit radios.

The strategy was to mount the radios as close to the antenna as possible to obtain the maximum 24dB out of the radio and feed the signal straight into the 14dBi gain sector antenna. This design would eliminate the noise from an amplifier and provide a strong signal out of the sector antenna.

Design analysis showed that this standard implementation did not provide enough gain to transmit the required 10 miles.

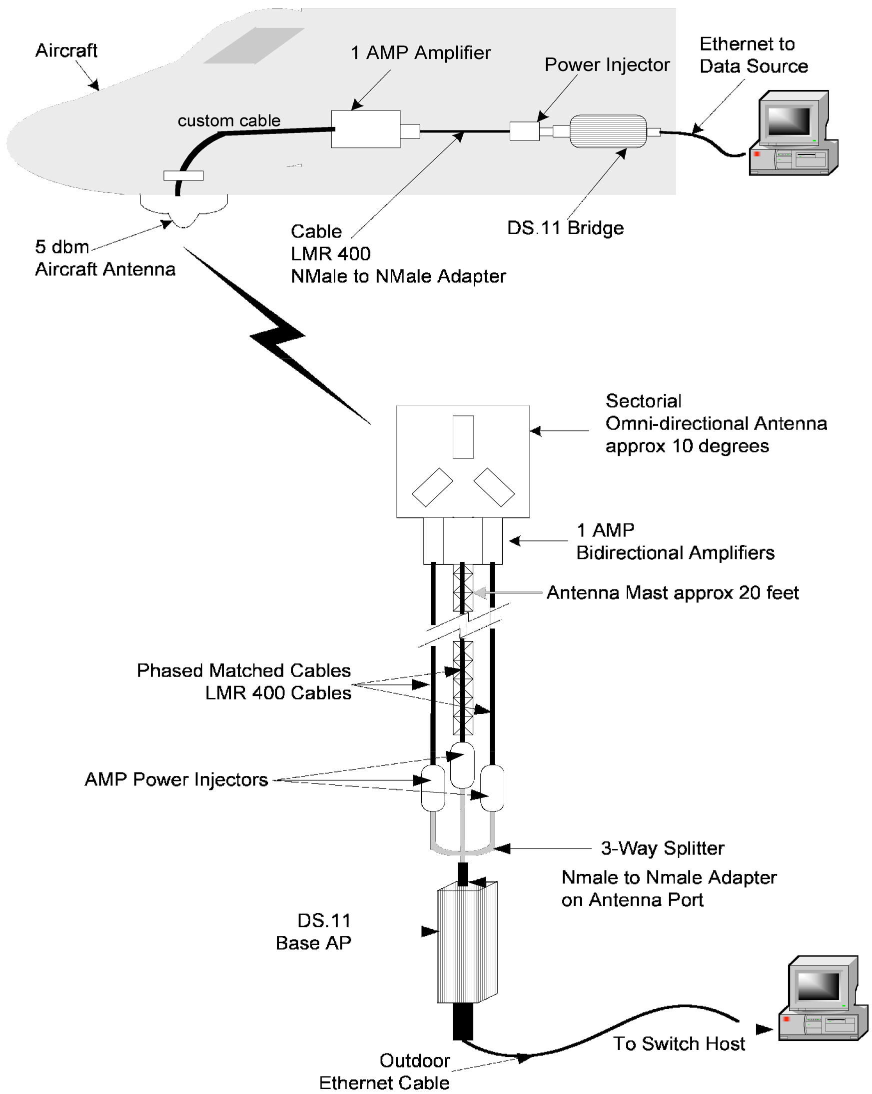
The goal of version two designs was to increase the gain. The version one design was modified to incorporate a power injector and an amplifier right before each of the sectors. This solution allows the radios to stay on the ground rather than mounted on the tower.

Design analysis showed that while this implementation provided enough gain, an unacceptable delay was caused by reassociation. In the RIPCom system, reassociation occurs when the aircraft received signal moves from one sector of the antenna to another. These radios can perform handshaking to determine which radio is receiving the strongest signal from the RF source. The radio with the strongest detected signal will take over the reception responsibility. The reassociation process can take up to 1400ms with the DS.11 radios. That amount of time is unacceptable for maintaining a solid network connection.

To solve the reassociation issue, a single Base Unit radio was used. The version three designs configuration incorporated a DS.11 radio, followed by a power injector, then a splitter followed by an amplifier just before the input of each sector of the antenna. This configuration eliminated two of the radios, two power injectors and added a three-way splitter.

Version three designs greatly simplified the system as well as reduced the cost. However, it introduced two questionable features: 1) would the three-way splitter pass DC current, and 2) would one power injector adequately feed all three amplifiers. The manufacturer of each of the two components was involved in resolving these questions. The splitter manufacturer performed several tests on the part and verified that it would pass DC current. However, the amplifier manufacturer confirmed that one power injector could not provide enough power for all three amplifiers. The manufacturer volunteered to build a single power injector that could perform this task, but the expense of building the new power injector was cost prohibitive.

Lessons-learned and design analysis from the first three design versions came together to define the final solution for the RIPCom Ground Station USFS application. The final design (shown below) places the three-way splitter directly after the DS.11 radio and adds power injectors and amplifiers to each output of the splitter. Phase matched LMR-400 cables are utilized in the final configuration of the system to eliminate phase mismatching issues. Based on the final technology design solution, a detailed architecture was identified for the USFS application. The following diagram details the components used in this solution



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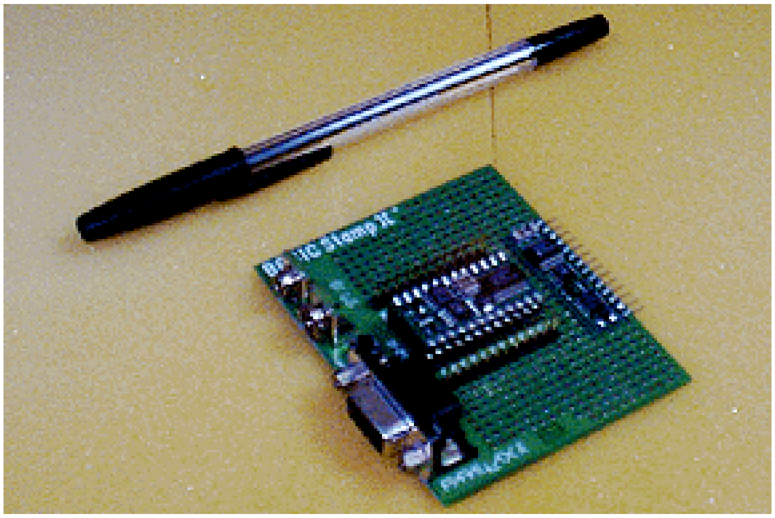
Example RIPCom Application

Intelligent On-board Systems

Mitigating safety and risk on a vehicle that does not have a human in the loop can be a daunting problem; it implies that some kind of intelligence and decision-making capabilities are required. A solution is the use of Periphery Interface Chips. (PICs) UAV's intelligence can be defined in terms of PIC implementation. PICs can be the primary method of endowing the UAV with intelligent decision-making under non-nominal conditions. These reprogrammable microprocessors can be assigned specific functions throughout the UAV's avionics, some more complex than others depending on their functionality and criticality.



There are three major areas under which these PICs can function: data flow control, catastrophic decision control, and telemetry quality monitoring.

The use of PICs in data flow control allows for instantaneous reliable decision making when a command is received from the ground system. In a UAV, data flow control will constitute the rerouting of data packets to specific on-board avionics. A configuration can consist of a PAL PIC to control data flow between the two autopilots and the on-board computer. Since not all systems can talk at the same time through a serial communication's line, a priority has to be set by the ground system as to which component you wish to receive and/or command via the RF link.

Telemetry quality monitoring refers to the ability of a system (PIC in this case) to judge the correctness of a data set, which is used by a critical operational component. For a UAV, the PIC will be monitoring the data quality of both (primary and backup) inertial sensor systems; such as, a differential GPS and a piezo-gyro system. If the PIC determines that the sensor readings used by the primary navigation system are incorrect or not good enough, it will automatically switch over to the secondary navigation system. If it then senses that the secondary navigation system is also malfunctioning, it will notify the catastrophic decision control system for appropriate action.

Catastrophic decision control is a critical function of a vehicle that has to instantaneously and autonomously respond to a single or multiple failures of vital UAV subsystems. An appropriate design for this type of scenario is a 3 PIC system that would monitor all vital avionics and communication links for failure. A logic table would be designed that would describe the possible failures and the appropriate actions. Based on experience, this type of decision-making should be performed on-board, thereby reducing human error and allowing a much quicker response time. The PIC design of the catastrophic decision control would incorporate three redundant PICs whereby 2 out 3 have to agree on what they are sensing. If there is agreement, the logic will initiate the appropriate preprogrammed action. An override link would also be built in as well as a direct connection to a possible parachute system.

The PIC systems would also be functioning, and interfacing with, the on-board computer, but would not rely on it, since it is a single point of failure and statistically, has a higher probability of failure.

Nevertheless, the on-board computer would undertake all nominal operations and data processing, results of which would also feed the PIC systems for possible decision making. Examples of this include instrument health, state of data acquisition, nominal start and stop, data logging and see and avoid processing. The latter sub-system would have to be treated as an added module to the UAV with multiple data paths, one to the on-board computer and one to the PIC system whereby instantaneous decisions and responses can be made.

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