Reducing Cost with Autonomous Operations of the Deep Space Network Radio Science Receiver

Sami Asmar, Aseel Anabtawi, Mick Connally, Andre Jongeling
Jet Propulsion Laboratory, California Institute of Technology

Abstract

As a world-class instrument for science research, the Deep Space Network is credited with many discoveries in planetary science reached via data acquired by the Radio Science Receiver. Various generations of this receiver (independent of the tracking receiver used for all mission support) have existed in the Network for about three decades, under various names and designs. The current digital Radio Science Receiver has built-in technology that allows autonomous operations that has been proven to increase efficiency, boost the statistics of valid data acquisition as well as save cost to the Network and flight projects. For specific Radio Science experiments, such as the Mars Global Surveyor atmospheric occultations occurring every two hours for many years, project-funded science staff configures the RSR with the appropriate tuning files derived from navigation information, the event-timing file, and acquisition configuration in advance. Autonomous operations need only spot checks, as opposed to constant monitoring needed on previous missions. This pioneering and visionary development on the part of the Deep Space Network has resulted in statistics above 95 percent of valid data acquisition for MGS over several thousands of occultations to date. This paper describes the Radio Science Receiver system and the savings it has brought to mission operations. The design and implementation of remote and autonomous operations will be discussed along with the process of including user feedback along the way and lessons learned and procedures avoided.

Introduction:

The Deep Space Network, as an instrument for Radio Science research, is credited with numerous discoveries in planetary science, space physics and relativity due to data acquired by the Radio Science Receiver (RSR). The RSR is independent of the tracking receiver used for mission support, and produces a different data type. It has existed in the Network (in various names and configurations) for about three decades exclusively for science experiments and special mission support.

Whereas the tracking receiver locks onto the spacecraft downlink carrier and tracks it within certain amplitude and frequency dynamics, the RSR is an open-loop receiver that is driven by a tuning prediction file generated on the basis of navigation-provided solutions of the spacecraft position and velocity relative to the supporting station. It utilizes a digital down-converter and recorder with user selectable bandwidths, sampling rate, attenuation, and other configuration parameters. Frequency and time offsets from

the "predicts" are user-entered parameters. Real-time displays provide spectral information as well as time-histories of the carrier level and frequency, estimated via a fast Fourier transform for quick-look evaluation purposes.

The Network currently contains a minimum of two receiver racks, each comprised of two independent reception channels, at each complex. Located at the Central Processing Centers, the RSR can receive input from all the 70-m and 34-m stations.

RSR Development

The success of the remote and autonomous operations of the Radio Science Receiver is mostly due to the excellent engineering of the RSR. The latter started with good requirements - performance requirements determined the quality of the data and operational requirements determined the ease of use of the system. The operational requirements for the RSR were based input from the RSSG and their years of experience with previous generations of Radio Science subsystems. While a good deal of the RSR is new, the RSR front end (digitizer and digital down converter) was based on the front end of the DGT FSR, which had demonstrated performance and reliability. The implementation team was relatively small, four software people, two hardware people, and two test people, thus promoting better communication.

The RSR developers worked closely with the users to obtain feedback throughout the development phases. The initial RSR software was in the hands of the users early in the development process and the design of the RSR was adjusted based on user evaluation and feedback. The RSR has been designed for remote and autonomous operations with client server architecture and scripted operation. The current digital Radio Science Receiver has built-in technology that allows autonomous operations that has proven to increase efficiency, boost statistics of valid data acquisition, and save cost to the Network and flight projects.

Remote Operations

The personnel at the stations of the Deep Space Network operate every delivered operational subsystem. The exception to this, however, is the Radio Science Receiver, which is operated by the Radio Science Systems Group (RSSG) remotely from JPL. The station staff can also operate the RSR when needed.

In this context, remote operations are limited to: electronically accessing the RSR, configuring it, acquiring the data, and transferring the data to JPL. No control of the antenna pointing or access to other data or subsystems is allowed. The RSSG, however, also remotely operates the Cassini Media Calibration Subsystem, a custom-built system placed adjacent to DSS-25 that does not fall in the "delivered operational" category.

The process of Radio Science data acquisition begins with the conversion of science objectives into to a required experiment, which then appears on the schedule of the flight project that is communicated to the DSN schedulers. After the pass has been scheduled, the RSSG generates tuning predicts using the PREDICT software and transmits the file to the appropriate RSR. Pre-pass configuration takes place prior to data acquisition using real-time displays for confirmation of the proper configuration.

In addition to remote operations, autonomous operations have also been very successful. For missions with repetitive daily experiments, it has proven effective to build scripting capability into the system. For the Mars Global Surveyor atmospheric occultation experiments, for example, occurring as often as every hour daily for weeks (two-hour spacecraft orbit with entry and exit observations) the configuration as well as the start and stop times of the data recording are predetermined and can be entered in a script file for unattended remote operations.

Conflicts in scheduling the RSR among projects have so far been resolved by the RSSG, acting as the representative for all the Radio Science investigators.

Motivation

Prior to remote operations, the acquisition of the Radio Science data required the attentive efforts of numerous engineers in the DSN as well as flight project and technical divisions especially during critical planetary encounters and tests leading up to those events. Intensive planning was required in order to submit inputs to the sequence of events, which included the receiver configurations many weeks prior to the experiment. Modifications to the configuration required many reviews, taking up valuable resources. Operator errors and/or failures to follow the sequence of events caused loss of science data.

Also in that era, there was extensive real-time monitoring of DSN operations by flight project personnel, and JPL-based DSN operations engineers. The complicated nature of the experiments and the long time separation between experiments rendered training of station personnel very difficult, as did the need for real-time changes which occurred in reaction to information on the health or performance of the spacecraft or the radio signal. The delay in communications when changes were requested jeopardized the quality of the data.

Figure 1 shows the process for Radio Science data acquisition prior to the introduction of remote operations. Figure 2 shows the process as it has been simplified by shifting the responsibility of data acquisition to the representatives of the flight project investigators.

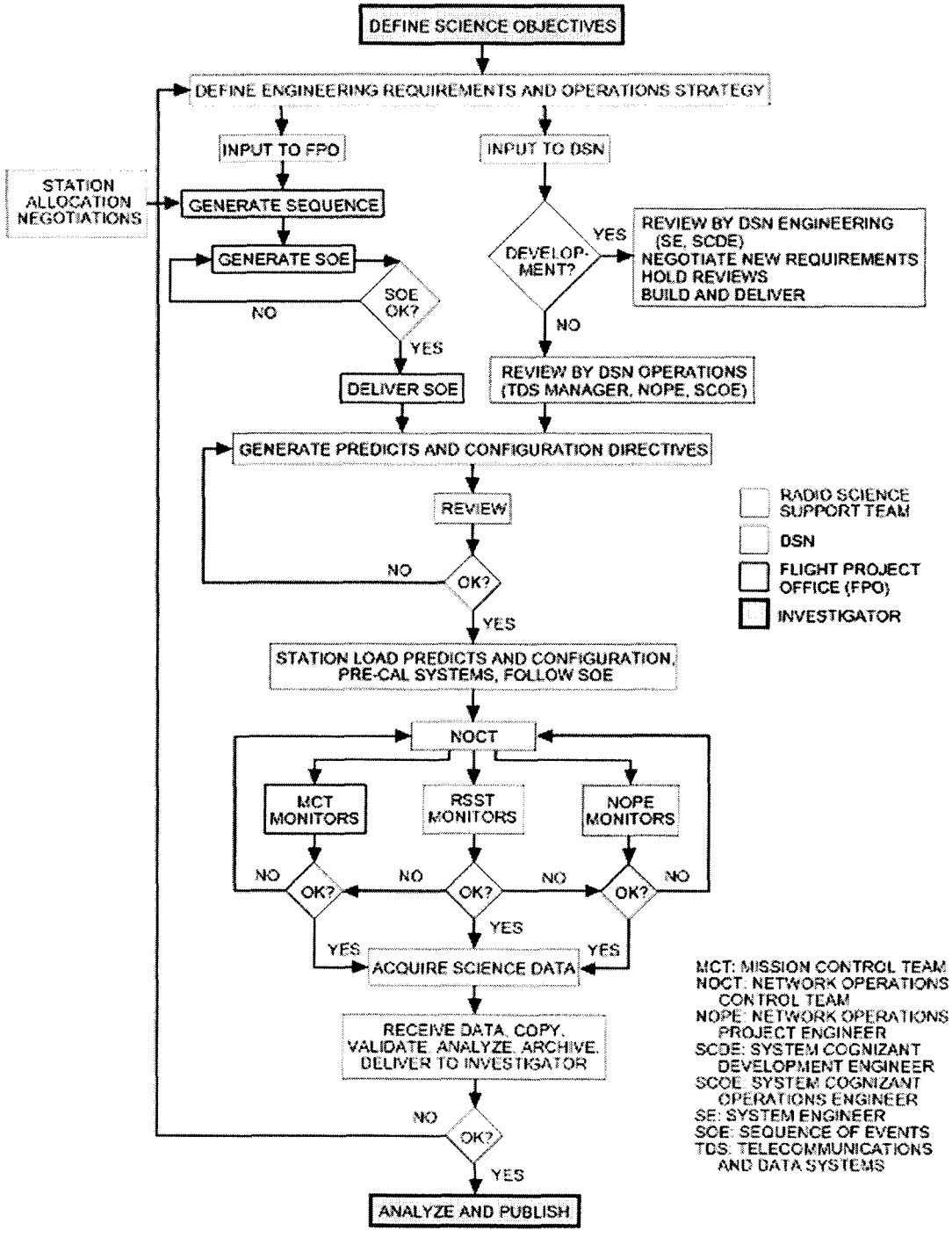
Results and Lessons Learned

This pioneering and visionary development on the part of the Deep Space Network has resulted in statistics above 95 percent of valid acquired data for MGS over several thousands of occultations to date. After the Deep Space Network introduced the remote operations of the Radio Science Receiver, there was a drastic reduction in the number of lost or degraded measurements due to operator error and a reduction (practically elimination) in the number of submitted Discrepancy Reports (DRs). The need for project monitoring of the operations was eliminated as the project representatives took over the responsibility for their own data acquisition. Overall, there was significant cost savings. The reduction in the amount of documentation and transmission of training material specific to project experiments, as well as the redundancy in the monitoring the experiments, has saved a great deal resources for sponsors.

Among the lessons learned from this experience, after several years of success, include the realization of the effectiveness of a small, motivated, highly trained multi-mission Radio Science team versus a more general operations team. Integrating flight project operations and DSN operations, in the Radio Science context, has proven to be very advantageous to both organizations. In addition, the simplification of organizational accountability, where organizational roles and responsibilities were agreed upon and documented before hand, has further increased the effectiveness of this method.

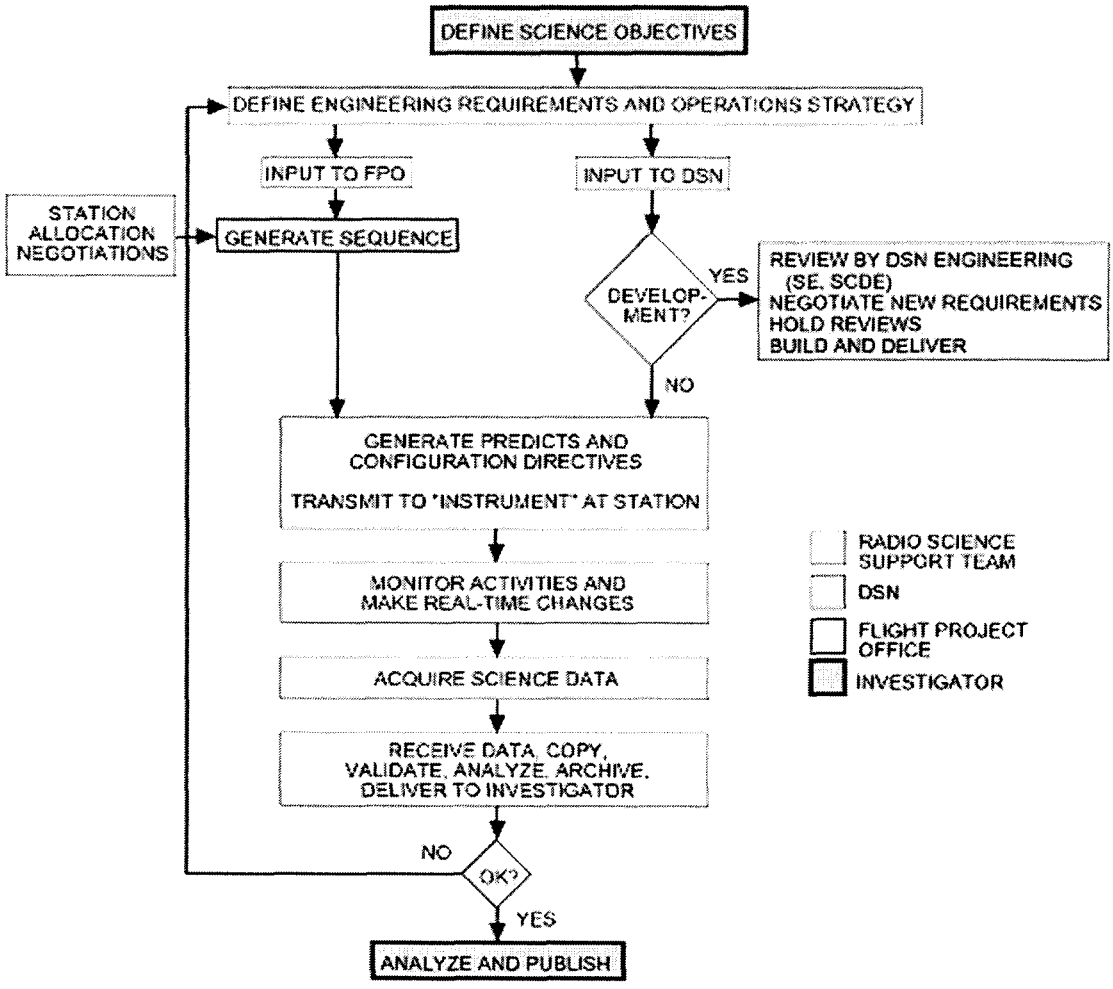
Future Work

The ability to react quickly to mission emergencies and support special spacecraft maneuvers, in addition to conducting Radio Science experiments, has made the RSSG a specialized "SWAT Team" among the many services of the DSN. Remote operations could be further developed to improve the existing interfaces and add robustness in order to provide the best possible customer support.



End-to-end radio science experiment process prior to remote operations.

Figure 1



End-to-end radio science experiment process after remote operations.

Figure 2