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THE LUCY MISSION SCIENCE OPERATIONS CENTER

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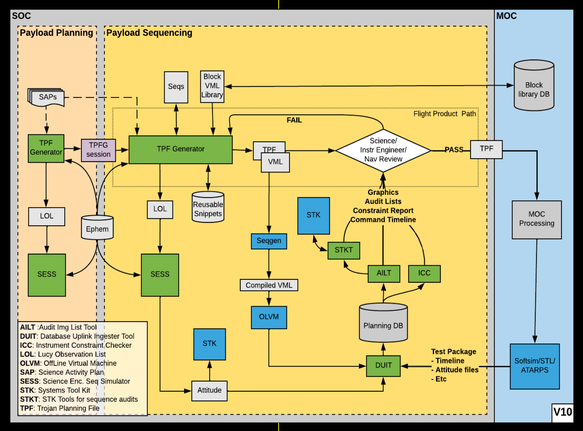
Overview

The Lucy mission will explore the Jupiter trojans, performing flybys of 8 trojans (four primaries - two with satellites - in the L4 cloud, and a binary in the L5 cloud) and two main belt asteroids. Lucy launched on 2021 October 16, and subsequent checkouts and calibrations showed that the spacecraft and instruments are in good health to perform the mission science goals. The Lucy ground system is comprised of the Mission Operations Center (MOC), Navigation Operations Center (NOC), and Science Operations Center (SOC). The SOC is responsible for planning & sequencing the payload operations in collaboration with the science and instrument teams, processing data from the payload, and data archiving. The SOC also provides access to Lucy payload data for the Lucy mission project teams. Here we present the design and capabilities of the Lucy SOC.

Uplink

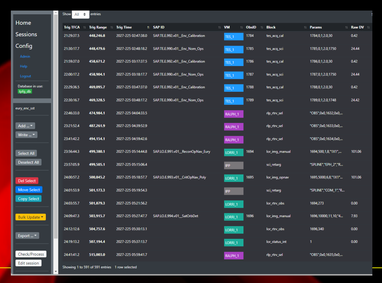
The Lucy SOC draws experience and has applied lessons learned from many missions, especially the New Horizons mission, both of which are flyby missions with similar instruments (L'LORRI and L'Ralph having New Horizons heritage). The payload planning and sequencing functions on Lucy are close replicas of the New Horizons processes, with improvements applied as needed.

The Lucy **Payload Planning** process is requirement driven. The science team transfers the mission science requirements into Measurement Techniques (MTs), which are narrative descriptions of requirements, desirements, and other cosiderations. The MTs are kept in Confluence, a web-based wiki part of the Atlassian suite, which also is used for communication, meeting notes, software documentation, operations, and task management. Making use of Confluence at the SOC has greatly facilitated collaboration, productivity, and tracking. Also kept in Confluence are the Science Activity Plans (SAPs). These are more detailed descriptions of the observations, used by sequencers when building a command load. Building the SAPs is a collaborative effort between the SOC, science team, instrument teams, and the NOC.

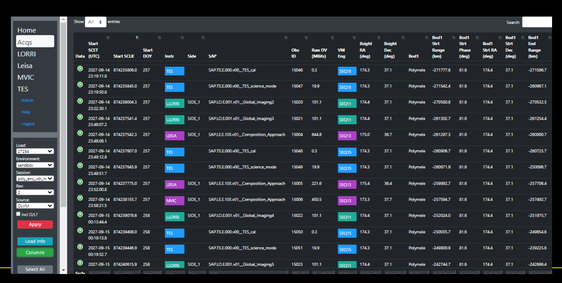


Payload Sequencing uses a tool developed by the Lucy SOC called **TPFG** (Trojan Planning File Generator), which provides a GUI for the command load building. It is written in Python using the powerful Django module and uses a PostgreSQL database on the backend for the VML block libraries, which are the building blocks of a command load that is built based on the SAPs. The command loads themselves (including all *versions* of each command load), therefore live in a centralized database and can easily be accessed by any sequencer at any time. In the Lucy mission, the commanding around encounter closest approach is range-based instead of being scheduled at absolute times; a TPFG user can select a SPICE meta kernel, and TPFG uses this to calculate range to time and vice versa, allowing the user to work in either time or range domain. TPFG checks for VML block collisions and ensures that enough margin is applied between blocks to account for time shifts that happen as the spacecraft systems automatically update the estimated distance from the target. TPFG calculates and tracks data volume for all science data. TPFG sessions can be merged, copied, handed off between team members, and exported to Excel or comma-separated format.

After a command load has been built, it needs to be reviewed and approved by all teams using the **AILT** (Audit and Image List Tool), another database-driven GUI tool built by the Lucy SOC. AILT also can export data for users who prefer reviewing command loads in Excel. The **STKT** tool automates generation of Systems Tool Kit (STK) graphics for visualization of the activities.



TPFG



AILT

Database

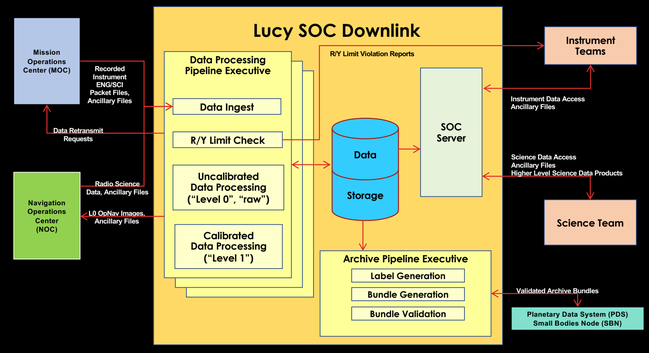
The Lucy SOC operations, pipelines, and data products are managed and connected by two databases – uplink and downlink – which are the core of the SOC system. These databases enable checking and end-to-end tracking of observations and their resulting data, from sequencing through processing, via observation IDs (OBSIDs, which also are embedded in the instrument data), target IDs, and data status (e.g., received, processed). Data are added to the databases using the following SOC-built tools:

- **DUIT** (Database Uplink Ingester Tool) ingests command timelines and observation details from MOC simulators, handling all uplink sequences used in testing and flight.
- **DDIT** (Database Downlink Ingester Tool) ingests the science and auxiliary data received from the instruments and spacecraft.

Downlink

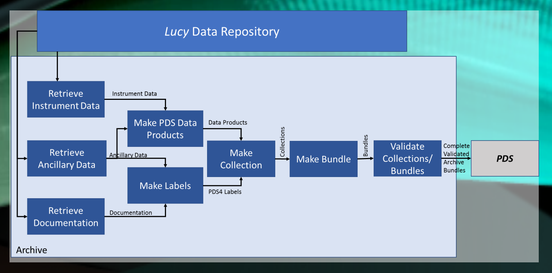
Lucy downlink activities are primarily to perform science data checking and processing to generate uncalibrated (UDP) and calibrated (CDP) data products. The SOC also performs instrument health and safety monitoring as a backup and extension to the real-time monitoring performed by the MOC.

After the data have been downlinked from the Lucy spacecraft through the Deep Space Network to the MOC, the SOC performs automated pulls of the data bundles (compressed instrument data packets and auxiliary data), runs them through the UDP/CDP pipeline, and places the resulting data files (in FITS and HDF5 format) on the SOC server where project members can access them. For critical optical navigation data that need to be processed by the SOC within an hour, those data are also processed by a parallel SOC pipeline on an offsite server located at the MOC, providing redundant processing and access.



Archive

The Lucy SOC builds the data products, collections, and bundles and submits them to the NASA Planetary Data System (PDS) Small Bodies Node (SBN) for permanent archiving. These data and their labels are all PDS4 compliant. The archive pipeline is comprised of a bundle generator, XML label generator, and bundle validator. Deliveries follow the Lucy Data Management and Archive Plan (DMAP), and encounter data typically will be submitted to the PDS for peer review and public release within six months after completing receipt of all the data on the ground.



Environment

All Lucy SOC activities are run on multiple virtual machines within a Linux environment. This design allows for ease of updating software or doing a complete re-installation, and provides an excellent environment to optimize flexibility, access, use, and security. The security of the system, access, and integrity all conform to NIST 800-53 controls.