National Aeronautics and Space Administration

Systems Analysis

In-Space Propulsion Technology Project

NASAfacts

The In-Space Propulsion Technology (ISPT) Office is investing in propulsion technologies to meet future science missions' needs. Our current efforts include advanced chemical propulsion, aerocapture technologies, and electric propulsion with an objective to provide increased science payload capability while decreasing trip times, cost and risk.

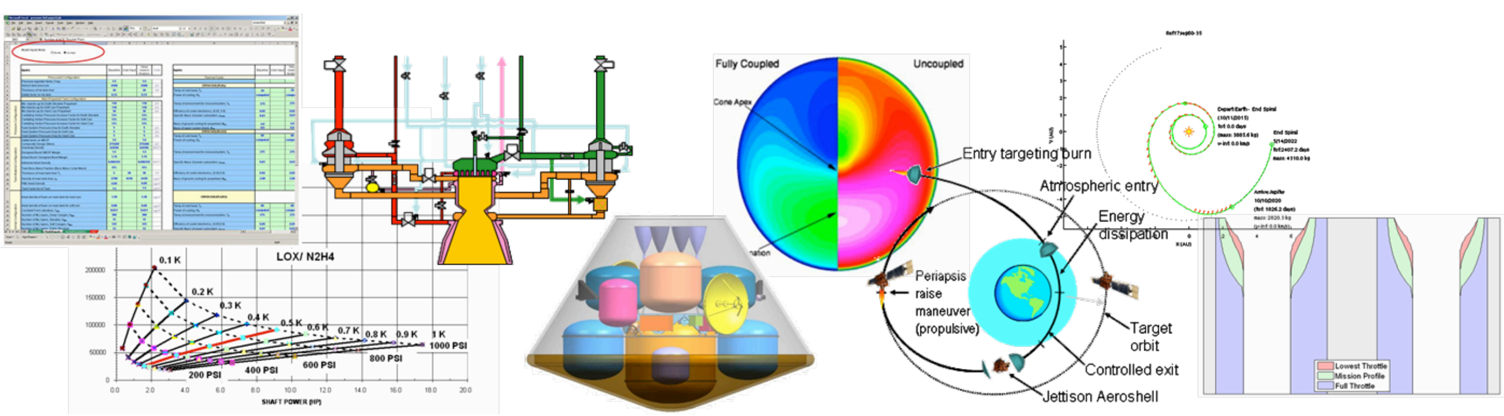
A strategic area of investment for ISPT is on systems analysis. Systems analysis is used during all phases of any propulsion hardware development. The systems analysis area serves three primary functions: to help define the requirements for new technology development and the figures of merit to prioritize the return on investment, to develops new tools to easily and accurately determine the mission benefits of new propulsion technologies, and to assist mission planners, potential ISPT technology users and reviewers better understand and evaluate new propulsion options.

Systems Analysis for Focused Investments

The first activity following the inception of ISPT was the Integrated In-Space Transportation Plan (IISTP). There are a myriad of propulsion systems for various mission niches, however; resources do not permit development of all options. Also, the intent of the ISPT office is to develop propulsion technologies for a wide range of unknown potential missions with unknown requirements for future competed missions. A technology prioritization was performed to: develop baseline NASA Science Mission Directorate (SMD) propulsion requirements, define architectures utilizing ISPT technologies, and provide recommendations for ISPT investments.

With a focus on flagship missions, the key technologies considered enabling were aerocapture and electric propulsion. The state-of-art propulsion technologies were considered inadequate to meet mission needs to several high priority science targets. A direct result of this study led to the procurement of both aerocapture technologies and NASA's Evolutionary Xenon Thruster (NEXT). Both the aerocapture and NEXT programs are completing their technology development activities and are providing products eligible for NASA science missions that would be otherwise infeasible within the time, cost and allowable risk of a specific mission development.

The ISPT systems analysis project area also performed a "re-focus" study to evaluate technology investments specifically for the lower cost capped Discovery and New Frontier missions, and identify any propulsion technology gaps. Results from the study led to the shift of the High Voltage Hall Accelerator (HiVHAC) to a low-power thruster specifically to address low-cost electric propulsion needs, a shift in the NEXT throttling range to increase low-power operation, and the elimination of "hard" cryogenic propulsion investments. Follow-on analyses also led to the specific design requirements of the HiVHAC



including peak operating power, throttle range, specific impulse, and lifetime capability.

Mission application studies, publications, and public outreach are also significant to the infusion of new technologies. Systems analysis has published over 100 publications on the mission benefits and application of ISPT technologies; references can be found on the project website.

Systems Analysis Tool Development

Another focus of the systems analysis project area is the development and maintenance of tools for the mission and systems analyses. Improved and updated tools are critical to clearly understand and quantify mission and system level impacts of advanced propulsion technologies. Significant tool development efforts have been on the Low-Thrust Trajectory Tool (LTTT) suite, the Aerocapture Quicklook tool, and the Advanced Chemical Propulsion System (ACPS) tool.

Low-thrust trajectory analyses are critical to the infusion of new electric propulsion technology. Low-thrust trajectory analysis is typically more complex than chemical propulsion solutions, and requires significant expertise to evaluate mission performance. While some of the heritage tools have proven to be extremely valuable, many cannot perform direct optimization and require good initial guesses. This can lead to solutions difficult to quickly independently verify.

The ability to calculate the performance benefit of complex electric propulsion missions is also intrinsic to the determination of propulsion system requirements. To that end, the in-space propulsion technology office has invested into multiple low-thrust trajectory tools that can independently verify low thrust trajectories at various degrees of fidelity.

The ISP low-thrust trajectory tools suite includes Mystic, Mission Analysis Low Thrust Optimization (MALTO) program, Copernicus, and Simulated N-body Analysis Program (SNAP). SNAP is a high fidelity propagator; MALTO is a medium fidelity tool for trajectory analysis and mission design, Copernicus is suitable for both low and high fidelity analyses as a generalized spacecraft trajectory design and optimization program, and Mystic is a high fidelity tool capable of N-body analysis and is the primary tool used for trajectory design and analysis of the Dawn mission.

In 2009, the ISPT project released its Aerocapture Quicklook Tool, formally the multidisciplinary tool for Systems Analysis of Planetary EDL (SAPE). SAPE is a Python based multidisciplinary analysis tool for entry, decent, and landing (EDL) at Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Titan. The purpose of the SAPE is to provide a method of rapid assessment of aerocapture or EDL system performance, characteristics, and requirements. SAPE includes integrated analysis modules for geometry, trajectory, aerodynamics, aerothermal, thermal protection system, and structural sizing.

Another significant investment has been made of the ACPS tool. The ACPS tool can quantify system level impacts to modifications of a chemical propulsion system. System levels impacts are necessary to understand true implications of technology modifications, e. g. increasing the pressure to increase performance may lead to increased feed system mass or qualification of higher pressure tanks with an overall negative net effect for the mission of interest. The ACPS tool is undergoing validation with intent for public availability.

The ability for the user community to rapidly and accurately assess mission level impacts of ISPT technologies can ease technology infusion. Every effort is made to have these tools validated, verified, and made publicly available. While some of the tools are export controlled, instructions to obtain all of the tools are provided on the ISPT website listed below.

More about the System Analysis Technology Area

Research in this area is being funded by the In-Space Propulsion Technology Program, which is funded directly by NASA's Science Mission Directorate in Washington and managed by the In-Space Propulsion Technology Office at Glenn Research Center in Cleveland, Ohio. The program's objective is to develop in-space propulsion technologies that can enable or benefit near and mid-term NASA space science missions by significantly reducing cost, mass and travel times.

For more information about NASA's In-Space Propulsion program and available tools, visit:
http://spaceflightsystems.grc.nasa.gov/SSPO/ISPTProg/

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