COMING TO GRIPS WITH SCIENCE

Applying The Aerospace Corporation's Genetic Resources for Innovation and Problem Solving (GRIPS) to Optimize Science Missions

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Abstract

When designing a space science mission, there is always a tradeoff between observationt and cost, in which one would like to collect as many samples as possible in order to bound the problem in spite of having a limited budget. This has historically led to individual or small clusters of satellites filled with high-end, custom-built instruments. The space community is moving into an era in which large constellations are becoming affordable, and there are more launch opportunities available. This brings a new complication of determining the sets of orbits that can optimize the science returns within the given constraints. The Aerospace Corporation has developed a tool called Genetic Resources for Innovation and Problem Solving (GRIPS), which allows scientists to quantify the tradeoffs when developing a new mission or observational campaign, often providing solutions that may have not initially been considered. We see GRIPS as an innovative tool that will help optimize the science outcomes of a space mission.

Introduction

Since the start of the Space Age, there has been a whisper and a wish that we would be able to eventually move away from a sparsity of in-situ observational points and move to a global view of the magnetosphere. Throughout the decades, constellations have been proposed for such a change, including the geospace multi-probes and most recently, the magnetospheric constellation mission Dynamic Response and Coupling Observatory (DRACO). What has limited our ability to get such a mission off the ground? Costs have, but with the increased ability to move from custom-built instruments to an assembly line production for satellites, there is renewed hope for the development of such a large-scale constellation.

With the recent advances of CubeSats and SmallSats, the community is approaching an era in which one can use off-the- shelf instruments and satellite designs. This has greatly lowered the bar of entry into space, allowing for many new and successful, primarily Low Orbit Earth (LEO) missions (e.g., CSSWE, FIREBIRD, AC6, petiteSat). Recently, there has been a push for these CubeSats to move beyond LEO into geo-transfer orbits (Shields 1), and beyond (Mars Cube One).

With the success of "off-the-shelf" hardware and instruments and a plug-and-play design concept, the research community can start to re-think how we design magnetospheric and space weather missions. While we are likely to continue to have single or small-constellation, highly instrumented missions (e.g., MMS, GOES), the research community is coming to a time when we can augment and bound these non-unique observations with a space science infrastructure comprised of many distributed SmallSats or CubeSats with minimal instruments (e.g., a magnetometer and/or dosimeter). This infrastructure would be analogous to the system of weather stations and Doppler radars, while the larger satellites would be analogous to the hurricane hunter planes.

With the potential for large-scale constellations, a new problem arises. How does one optimally design a constellation for the given science objectives, downlink constraints, number of launch opportunities, and other feasibility issues? The Aerospace Corporation has developed a tool called Genetic Resources for Innovation and Problem Solving, or GRIPS, which can be used to search large trade spaces for potential solutions.

GRIPS is a decision-support process that combines multi-objective optimization with visual analytics to identify design tradeoffs for a wide range of problems. The process begins with the identification and formulation of a problem into design parameters, key objectives, and constraints, if any. Computational models, which may be nonlinear, multi-modal, discontinuous, discrete, or any combination thereof, are built to represent the desired problem formulation. Non-dominated solutions and key tradeoffs are identified through the use of evolutionary algorithms. These results are conveyed to decisionmakers via interactive visual analytics. The GRIPS process is repeated until the decisionmakers are confident in the model and have gained understanding in the key decisions to be made.

Discussion

We see opportunities for GRIPS to optimize our science returns, both before and after launch.

GRIPS is an innovative tool that can help aid scientists in the informed selection of constellation designs for their mission and science objectives. By using GRIPS and working with the GRIPS team, researchers can perform deep dives into the results to better understand the tradeoffs between potential solutions. We envision that this could become a standard step in any mission design with NASA to ensure optimal science returns. During phase A, or after a selection, a proposal team could utilize GRIPS to take their initial objectives and constraints and modify launch and orbit plans based on their selection from a trade space of optimized results.

GRIPS can aid planning—not just for the best science returns, but also for getting data back down to Earth. GRIPS is able to optimize for downlink opportunities, either by determining how many ground receivers would be needed and where, or by constraining whichever ground receivers are available. This can also be useful when planning what perigee, storage size, antenna, and power would be required.

After a satellite has been launched, GRIPS can help make the most of satellite missions by optimizing for potential campaigns and conjunction studies with both in-situ and ground-based instrumentation—to enable dynamic mission planning. We believe that GRIPS could be made available through small grants to help with conjunction studies between in situ and ground instrumentation in order to extend the science returns from existing missions that are taking advantage of the underutilized conjunctions and ground-space studies.

As a mission ages, there is a push to move onto the next new mission idea. However, it is often useful and cost-effective to continue to fund existing missions that continue to contribute new science returns and help constrain observations of other missions. These merits and new science objectives are often discussed through the senior review process which, as with humans, can be very biased and would benefit from the GRIPS decision support process. GRIPS could be used to inform these discussions, providing insight into what impacts on the heliophysics fleet a mission’s removal would have. GRIPS can account for these new identified compelling science questions of the current heliophysics fleet and look at solutions both with and without the mission in question. This is just one potential way that GRIPS would better inform the senior review decision process.

There is perhaps a cultural shift that needs to occur, as well. Launching spacecraft, even CubeSats, can be quite expensive, so there is a hesitation and a fear of missed opportunities if we do not outfit each endeavor with as many high-end instruments as possible. With this comes the tradeoff between a scarcity of points observed but a complete picture at that location vs. an incomplete picture of all plasma conditions but a global perspective. Historically, most of our heliophysics missions have focused on questions about microscale dynamics. However, there are compelling macroscale science questions that may now be feasible to address, looking at a global view of the dynamics throughout the magnetosphere during a single event. GRIPS is able to help us quantify the scale size of a constellation and other trade spaces, allowing for better-informed decisionmaking through context and discussion of what science is most important to capture.

Conclusion

Performing science in nature is always a tradeoff between observation and cost, in which one would like to collect as many samples as possible to bound the problem and observations in spite of having a limited budget. This has historically led to highly instrumented individual or small clusters of satellites. We are moving into an era in which larger and larger constellations are now affordable, as instruments and satellites are being developed to be made on an assembly line. Along with it becoming easier and cheaper to build a satellite, there are increasing sets of launch locations and opportunities. As it has become easier to collect data, the new limiting factor is getting the data back to Earth. This brings new complications in determining a set of orbits that optimizes science returns within these constraints: downlink opportunities, launch opportunities, access to regions for data collection, costs, ect. The Aerospace Corporation developed a tool called Genetic Resources for Innovation and Problem Solving (GRIPS), which allows scientists to quantify and see the tradeoffs when developing a new mission or campaign, often providing solutions that may have not initially been considered. We see GRIPS as an innovative tool that will help us optimize missions in order to address previously unfeasible yet compelling science questions in this new era of space.

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