NASA's Current Initiative to Improve Operations Planning

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***Abstract*— As a follow-on to the Technical Capability Assessment Team, in 2015 NASA began seven Agency-wide efforts to seek out opportunities to improve the effectiveness of NASA operations. One of these technical teams is the Mission Operations Planning team, charged with increasing interactions and efficiency for planning of mission activities. That team is chaired by the author with representatives from eight other centers across the Agency. As the strategic architects for the vision of agency-wide ops planning, the team has identified a number of new initiatives and techniques to improve planning, including: breaking down walls within centers which obstruct multi-mission planning; breaking down walls agency-wide which obstruct the sharing of ops planning lessons and capabilities; strengthening the community of practice of ops planning capability developers; establishing best practices for a variety of types of ops planning; defining standards for activity plans and timelines, and plan inputs; and recommending the presence of "multi-mission operations champions" within each center to implement these recommendations into the next decade.**

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1. INTRODUCTION: MISSION OPERATIONS AND NASA LEADERSHIP

NASA Mission Operations covers a broad spectrum of mission types across spaceflight and aeronautics, including deep space, low earth orbit, and atmospheric missions, and includes preparations for launch through disposal. Operations constitutes a substantial portion of NASA resources: 10% of the yearly budget and 13% of the total Agency workforce. In 2012, NASA formed a Technical Capability Assessment Team (TCAT) chaired by Associate Administrator Robert Lightfoot and Deputy Associate Administrator and former NASA Langley Director Lesa Roe which was aimed at developing a new operating model for the agency. For operations, this included: encouraging centers and missions to work together and share innovative ideas and lessons learned; establishing standards across the Agency; and sharing capabilities between centers. As a follow-on to the TCAT, in 2015 the Mission Operations Capability Leadership team (MOCL) was formed, along with seven Integrated Task Teams (ITTs) that were chartered to carry out the TCAT charge and conduct "deep dive" analyses into areas most able to effect improvement in how NASA performs operations. The MOCL is comprised primarily of project managers, whereas the ITTs are comprised primarily of practitioners, i.e. engineers with long experience in the field of operations connected to their ITT. The ultimate goal of these teams is to enable the Agency to improve operations efficiency, mission safety, mission success, and operability by encouraging innovations and sharing best practices across NASA's suite of missions. The MOCL was led by John McCullough (JSC) in 2015-2016 but has since been chaired by Steve Koerner (JSC).

The foci of the MOCL and ITTs since inception have been as follows:

1. Catalog current reusable functions, services, and capabilities
2. Gather, record, and deploy operations best practices
3. Develop a strong community of practice to guide and raise awareness of available capabilities, including best practices, as well as architect the next generation of operations (to avoid "reinventing the wheel")
4. Create the vision for future Agency mission operations, design the path that must be traveled to achieve this future, and deliberately engineer mission operations and NASA center evolution and alignment

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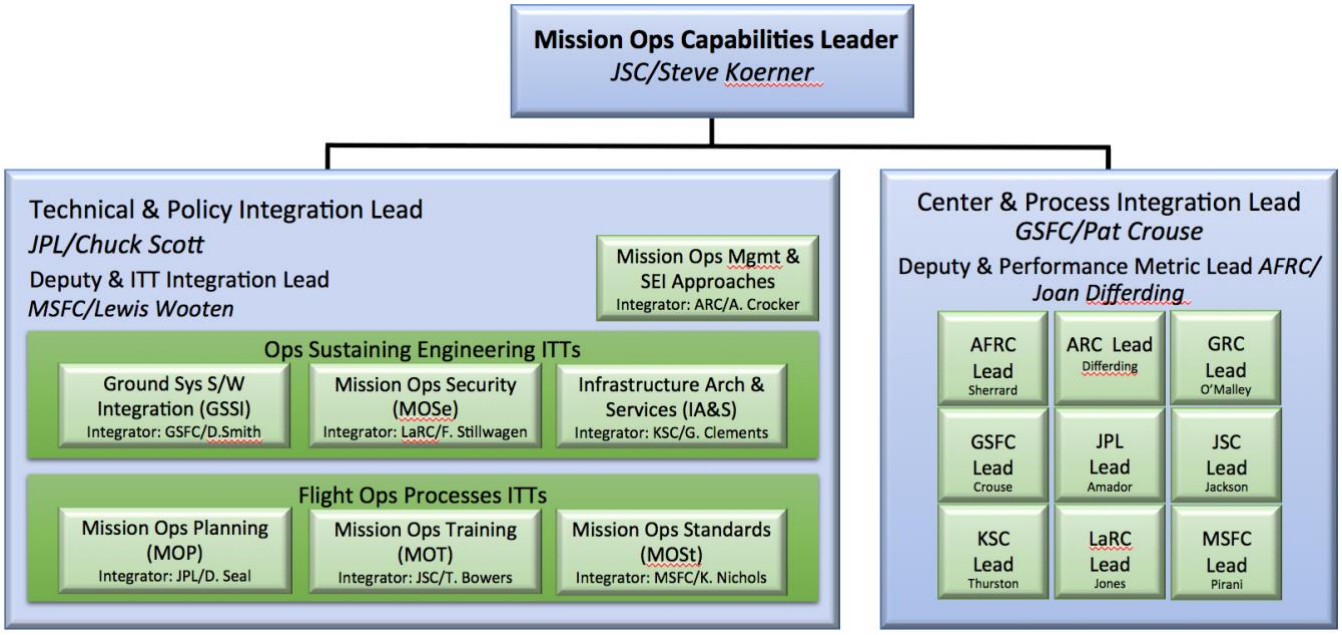

Figure 1. NASA Mission Operations Capability Team

The team (see Figure 1) draws its participation from the nine NASA centers that conduct significant operations: Armstrong (AFRC), Ames (ARC), Glenn (GRC), Goddard (GSFC), JPL, Johnson (JSC), Kennedy (KSC), Langley (LaRC), and Marshall (MSFC). The organization also includes lead representatives at each of these centers (shown on the right side of figure 1) to manage the center's participation as well as advocate for and deploy the resulting recommendations.

Figure 1 illustrates the organization of the MOCL and ITTs. The seven ITTs each have one representative from each of the nine operations centers and are chartered to focus on: Mission Operations Management and Systems Engineering; Ground Systems Software Integration; Security; Infrastructure Architecture and Services; Planning; Training; and Standards. This paper focuses on the accomplishments to date of the Planning ITT at lower left in the figure. All of the ITTs have conducted their business via biweekly telecons and once-per-year face-to-face meetings hosted at a NASA center; in addition, all of the team leads (essentially everyone listed in figure 1) also have monthly telecons and once- or twice-per-year face-to-face meetings.

To date, the MOCL and ITTs, as well as the Planning ITT in particular, have not delivered mandates or operated from a "thou shalt" attitude. Instead, they have collected recommendations and resources that the team believes will be adopted at each center via meritocracy, and recognize that there is broad support for the sharing of resources that should help infuse the team's recommendations into NASA culture.

There has been admittedly some speculation as to whether this effort was akin to previous, now defunct, efforts such as Faster Better Cheaper, ISO 9000, etc. With these activities, the Agency earnestly studied overlaps and synergies, but the effort ultimately dissipated, due arguably to the lack of commitment and resources to permanently infuse the recommendations into NASA culture. Arguably, each effort ran its course and did some good. While it is not yet clear whether the MOCL/ITT effort will run to completion and effect lasting improvements, there is team-wide acknowledgement that NASA operations capabilities are heavily stove-piped, with centers performing similar functions and developing capabilities that could be shared, and there are significant savings that can be realized. The team members have made significant progress and remain engaged and energized after 18 months of study, and the effort is approved to continue throughout FY2017 via recent Agency Management Council direction.

2. The Mission Operations Planning Team's Progress To Date

The Mission Operations Planning (MOP) team formally kicked off in August of 2015. The bulk of the fall of 2015 and winter of 2015-2016 was spent, as expected, in discussions of scope, i.e. specifically what operations planning means to the group, and then in surveys of the methods and tools that each NASA center uses to perform mission planning, with each center's rep leading sequential discussions. We placed an early priority on trying to evolve from talk to action as soon as possible.

For our purposes, we have defined "mission operations planning" to be architectural (ops concept-related), strategic (long-term), and late-phase (short-term) planning of mission-related activities to take place aboard a flight vehicle(s), from ground preparations for launch through

disposal. These activities are planned by ground teams and executed by air and space systems, payloads, and/or crew, and the period of their planning covers initial conception up to detailed sequencing shortly before execution. In some cases, this planning period may include a planning phase which concludes with the executable plan, but these practices focus not on the minutiae of detailed sequencing, but rather on the arrangement and attunement of activities, resources, teams, and products directly related to the flight events necessary to accomplish the primary mission goals.

In March of 2016, the MOP team held its first face-to-face meeting at JPL. Best practices for planning were reviewed and authored; planning tool demos were performed; past and current planning-related conferences were described; existing multi-mission sources of ops capabilities (e.g. AMMOS) were assessed; and guest lectures by JPL planning and ops experts were given.

Since March of 2016, we have focused on authoring best practices; considering planning systems and processes in use by the wider (external to NASA) industry; and initial scheduling of a NASA-internal operations planning workshop to begin extending the community of practice outside the MOP team.

Our path has not been without its obstacles. First, the scope and scale of planning varies widely between NASA centers. Each center conducts planning on a different scale, often for different missions, and across a variety o

f lifecycles. The lingo, tools, project organizations, and processes are all different, and it has taken time for us to learn each others priorities and language. KSC planners focus primarily on pre-launch preparation and launch operations; similarly, AFRC exclusively conducts short-duration aircraft flight operations with less pre-flight preparation than would be the case for long-duration missions operated by GSFC or JPL. JSC conducts significant sustaining operations on ISS that does not mirror the standard NASA project lifecycle – etc.

Second, it has often been challenging to maintain the team's attention. Each ITT is charged at a 5-10% level of effort task, and our activities often take a back seat to our primary duties which generally have customers that we more frequently see face to face. Regular telecons and the setting of intermediate goals has been helpful.

Third, it has been surprising to discover that not only do our centers perform planning differently from each other, but within our own centers, there is often significant stove-piping from project to project. We may make recommendations for all centers, and help develop multi-mission planning systems, but we each have work to do within our own houses to encourage our own center to adopt them.

On the other end, the team has drawn the most inspiration from four key areas. First, the Ensemble project, of the 2000s led by Ames with participation from JPL, JSC, and MSFC, has resulted in operations capabilities currently in use to power both Mars Science Laboratory (the "Curiosity" rover) and International Space Station mission planning. MSL uses MSLICE and ISS uses OPTIMIS (and other applications) which are both tools derived from Ensemble. Ensemble, and its Eclipse platform, are aging and are not likely to serve in the future, but their development and architecture are inspirations to future multi-center and multi-mission planning.

Second, the ISS's Payload Operations Integration Working Group is another superlative example of inter-center collaboration. The POIWG had its 40th in-person meeting in July of 2016 and continues to set the standard for multi-

center and multi-customer interactions. They also continue to re-evaluate themselves and re-invent their agenda and format to suit the changing needs of ISS payload planning. They eschew overly general "big meeting" topics, splinters with no defined purpose, and topics targeted to ISS personnel (as opposed to payload customers).

Third, the recent explosion of fast, capable, extensible on-line tools to view data, telemetry, timelines is impressive. Technologies such as D3, elastic search, google docs, and cloud services have set a high standard for fast, extensible, available-everywhere tools.

Fourth, and perhaps most importantly, we have drawn inspiration from each other. Trite as it may sound, the MOCL effort is, at its core, about building relationships between NASA operations teams. The MOP team has a common commitment to be of use to our colleagues and get something done, rather than simply talk about it, and that has maintained our resolve.

3. BEST PRACTICES

The MOP group has developed a set of best practices, as have the other six ITTs, with the intent that these be infused into the culture of each center. The best practices represent a portion of NASA's core operations standards. They are drawn from 60+ years of flight operations experience, and represent the set of operations practices NASA projects should follow, in that non-compliance could represent long-term cost impacts, risk augmentation, and/or losses in efficiency. Each practice is grounded in lessons that have been learned on past projects, at times at great expense. Experience has shown that some cost overruns – if not outright losses – can be traced to inadequate planning or analysis of mission conditions that are foreseeable, as well as programmatic decisions that favor short-term cost savings over operability and long-term efficiency to an unbalanced degree. The best practices strive for the presence of operability in design – in balance with other factors.

The best practices represent an invitation – not a mandate, but an opportunity – to each Center, project, or program to discuss their operations planning policies with their upper management. The practices seek to establish standards of

uniformity only where standardization is judged to have significant and long-term benefit. They should not be viewed as required design, but rather a set of suggested practices that should be considered when operations planning is undertaken. The intent is merely to ensure that Centers and projects give the best practices adequate consideration, under the guidance of the center's senior engineering and operations experts and/or flight/mission directors.

Some of our best practices are highlighted below:

- Experience operations planners should be staffed beginning in early development, to ensure that project-level trades and concepts are made with appropriate consideration of operations planning impacts.
- Operations planners should develop a Mission Plan or Flight Plan that should be the controlling document for key and driving plans, resource budgets, and the outcome of activity-related trade studies.
- Projects should identify and manage critical events, first-time events, and irreversible events, and give them special handling during planning, testing, and operations.
- Flight event plans should give adequate consideration to ground schedules and resources, including ground turnaround time where applicable.
- Flight event plans should be captured in active, living models rather than in static products where feasible. (Reflecting the modern, model-based migration from products to models.)
- Operations planners should maintain contact with planners on other projects within their center, as well as planners at other centers. They should use the means of interacting with other planners to regularly assess and reuse available planning capabilities.
- Projects should allocate resources to continued development of planning capabilities throughout the lifecycle, not just in development. (As a corollary to this best practice, we have also recommended to MOC leadership that centers should allocate resources at the center level to develop and maintain multi-mission planning capabilities.)
- Projects should cultivate and follow standardized visualization and exchange formats for mission plans.
- Projects should capture lessons learned from planners and participate in cultivating the means by which those lessons are deployed to other projects.
- Operations readiness tests should cover the full range of realistic operating conditions, including nominal, critical event, and contingency operations.

4. THE OPERATIONS PLANNING WORKSHOP

Foremost in the mind of the MOP team as of the writing of this paper is the need to establish and maintain a NASA-internal (initially) operations planning workshop. Having informed ourselves of how planning works at each center, some of the capabilities currently in use, and the extent to which each center – and projects within each center – use home-grown tools that are not adaptable or extensible, we wish to replicate and expand upon the experience in a larger, though still modest, forum. The workshop should be attended primarily by planning practitioners – those that perform the activity planning and develop the tools – and not by project managers. The hope is that mission planners from each center will come together, discuss their planning processes, demo their tools, and via meritocracy, enable better processes and tools to arise organically which are inherently multi-mission (and multi-center) and have the potential to realize the cost savings that spurred the larger MOC initiative in the first place. After each workshop, attendees can then go back to their center and help communicate what developments are best adopted by their center's projects.

We seek ultimately to create and maintain an Agency-wide community of practice in NASA operations planning. Our goal is to make it known to planners across NASA – to insert into their consciousness as engineers – that there is a wider community that is, and has, developed capabilities that can be of use; a community that they can be a part of, and leverage when help is needed.

We do not seek through this workshop to mandate that all centers perform planning the same way. Instead, the workshop should be a forum where projects and centers can find out what capabilities exist, and get support on how to design the adaptations (in both tools and best practices) that will always be required for each individual project.

The MOP team is currently in the midst of planning the first operations workshop at the Johnson Space Center in August of 2017. This first workshop will have some aspects of a dry run, in a closed format, with each MOP center representative hand-picking 2-4 planners and planning developers to attend, and a flexible agenda. Future workshops would be open to any NASA planners, with the MOP team acting as the organizing committee and some limited approval process to maintain a workable total number of attendees.

The workshop will be a two-day affair, attended by perhaps 50 operations planning personnel. A sample agenda for the MOP planning workshop is shown in Figure 2. It will feature a mixture of presentations on planning processes, tool development plans, tool demos, reviews of standards and formats, as well as unscripted Q&A time to allow for ample interaction between attendees. Not all attendees would be required to make presentations, and presentations would not be required to be submitted in paper form, nor would they necessarily be published outside of NASA (at least initially). Presentations and demos would follow a plenary / splinter division depending on the scope of each subject.

DAY 1			DAY 2		
Plenary Sessions – Room A			Plenary Sessions – Room A		
9:00	Opening remarks, schedule, goals, keynote speaker		9:00	SOFIA Mission Overview	
10:00	ISS Payload Ops Working Group Update		10:00	Red Dragon Mission Planning NASA + SpaceX	
11:00	Mars 2020 Ops Planning Process		11:00	The Timeline data type and CCSDS	
12:00	Lunch		12:00	Lunch	
Splinters	Room B	Room C	Splinters	Room B	Room C
1:00	ISS OPTIMIS Tool Update & Demo	MPSweb web timeline visualization tool	1:00	Lessons learned in critical event planning	Aircraft rescheduling on short notice
2:00	Real time ops dashboard demo	How to build an STK plug-in	2:00	MSL and M2020 MSLICE tool demo	Automated scheduling with CLASP
3:00	Launch ops planning	Cosmographia demo	3:00	Dev team collaboration with SLACK	Orion drop test planning
4:00	DSN scheduling tool demo	SLS planning tool updates	4:00	Q&A with ARC Playbook dev team	ISS rodent research planning
Evening networking & social hour			Adjourn		

Figure 2. Sample Operations Planning Workshop Agenda

5. CONCLUSIONS

The primary purpose of this paper is to inform the NASA and industry mission operations community of this initiative currently underway which to date has not been overtly publicized. While these efforts are envisioned to remain internal to NASA for the near term, should they be carried forward long term, industry partners have a need to know and can potentially benefit from improvements in our operations processes. Open source planning capabilities and standards may also be developed which can be leveraged by industry, following the long and productive history of NASA technology being of benefit to the wider community. Furthermore, should readers of this paper have undergone a similar process by which their planning processes and capabilities were modernized, or held similar planning workshops, the author invites them to pass on advice or lessons learned that may be of use. NASA planners that are interested in hearing more about this development are also invited to contact the author.

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REFERENCES

The information contained herein is a direct outgrowth of the contributions of the above persons, and of the leadership shown in Figure 1. As far as the author is aware, this paper is the first publication which discusses the existence of the NASA Mission Operations Capability team and its efforts, and draws exclusively from the following NASA-internal presentations that have not yet been made public.

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BIOGRAPHY

David Seal *is JPL's principal engineer for mission planning, and has been working in the field since departing MIT where he received his B.S. / M.S. in Aerospace Engineering in 1990 / 1991. He has been the lead planner for the Cassini/Huygens mission, the Shuttle Radar Topography Mission (STS-99), and the NASA/ISRO SAR mission (NISAR). He currently supports JPL's Mission Systems Engineering section, JPL's planetary mission formulation program office, and NASA's Agency-wide Mission Operations Capability team in the domain of operations planning.*