“Built-In” Action/Issues Tracking and Post-Ops Analysis Tool for Real-time Console Operations

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Abstract—At Marshall Space Flight Center’s (MSFC) Payload Operations Integration Center (POIC) for the International Space Station (ISS), the Payload Communications Manager (PAYCOM) team, whose members speak directly with the ISS onboard crew with respect to NASA payload operations, has found a creative way to reformat a mandatory Daily Report to organize action items, standing reminders, significant events, and other comments. While the report keeps others apprised of PAYCOM’s current activities and issues, very brief summaries of the items are put into a “Roll Off Matrix”, including start and stop dates, resolution, and possible applicability to future ops. The matrix provides accountability for all action items, gives direct insight into issues regarding payloads, control center operations, and methods, yields indirect information on PAYCOM priorities and processes, and provides a roadmap for locating extensive details if needed. This paper describes how the Daily Report and Roll Off Matrix are organized, used, and inter-related to each other and the PAYCOM operations log. While the application is for a manned vehicle, the concepts could apply in a wide spectrum of operational settings.\(^1\)

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INTRODUCTION

Operational log-keeping has been practiced for millennia. A log can be a powerful tool for maintaining continuity between shifts, reconstructing events, resolving anomalies, and distilling better ways of doing things. Early spaceflight programs relied on handwritten logs, and even though console operators developed unique symbols or shorthand, the pace of operations was such that operators could only jot down the bare essentials of what they observed. Because logs were handwritten, searching for either specifics or trends was very time-consuming.

Formally, “The console log provides a method of reconstructing the activities of a given operating position for the following shifts’ use, for operations analysis, and a database for contingency or failure analysis.” and “Each POIC cadre shall keep an electronic console log of realtime events, which is a brief narrative of these events, are Greenwich Mean Time (GMT) time-tagged, and entered as the events occur.” [1]

Today’s inexpensive computers, office automation software, and “instant-replay” voice communications archive systems allow console operators to prepare extremely detailed logs by the end of their shifts. This is obviously helpful if event reconstruction is needed to analyze a specific incident whose date(s) is/are known, and for assessment of a relatively short flight lasting one or two weeks.

Long-duration missions such as those flown on the International Space Station present some new challenges:

- System or payload activities may span weeks or months, and a series of closely related activities may span years.
- Crew members fly for months, and their task loading can make it difficult for them to remember nuances and “gotchas” between performances.
- Ground support personnel are often involved with three or four ISS increments concurrently – while one is flying, others are in preparation or post-flight. (An increment is a complement of payloads and activities associated with a given ISS expedition, as well as the time frame that the expedition crew is onboard.)
- The sheer number of log entries related to a given topic can make analysis difficult, even if a text search is used to reduce the number of entries under consideration.

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\(^1\) U.S. Government work not protected by U.S. copyright
\(^2\) IEEEAC paper#1265, Version 7, Updated 2007:12:17
- Formal databases document details upon details of planning criteria, equipment anomalies, ground team anomalies, and so forth, but in terms of ready reference to help console operators get through their shift, they may provide so much background that the foreground goes underground.

- As international partners begin flying their modules, systems, payloads, and flight crews, handshakes across different partners’ hardware, software, and organizations will become more complex, no doubt leading to more idiosyncrasies and “unadvertised features”.

This paper is written from the perspective of the ISS Payload Communicator (PAYCOM) console position. PAYCOMs are responsible for realtime ISS crew communication for NASA payloads, which includes [1]:

- Space-to-Ground (S/G) communication with crew for NASA payload issues
- Preparing written material for the Daily Summary based on ground team inputs
- Managing voice and/or video conferences between the crew and payload ground teams
- Reviewing procedures and operations documents with an emphasis on crew issues
- Tracking crew questions and/or requests related to NASA payloads. Some of these are handed off to other positions based on intra-team coordination, but PAYCOM is the default actionee.

The PAYCOM console is nominally staffed during crew awake hours on normal workdays. This is typically 16 hours a day, 5 days a week; and the gaps in operator coverage accentuate the need for good handover and “cheat sheet” materials.

**DAILY REPORT AND ROLLOFF MATRIX**

*Evolution*

In the course of operating since 2001, PAYCOMs tried several methods for keeping up with questions and actions. Items that could be resolved within 1-3 days could usually be managed via handover entries in the console log, but longer-term items tended to “drop through the cracks”. The “Tasks” feature of the email system (Microsoft Outlook) was used for a while, but problems included subfolder management, disappearance of items due to inadvertent mouse clicks on checkboxes, frustration/wasted motion due to nesting of messages and enclosures, and how easy it was to forget to check the system, especially on hectic days. Filing schemes for email messages outside of the “Tasks” structure yielded similar results.

At a PAYCOM meeting in early 2007, someone noted that all of the methods attempted were internal to the PAYCOM team – no other console position had insight into what we were tracking unless they’d made a note of it themselves, and their notes might not agree with ours.

It occurred to us that a Daily Report (DR) that we’re required to submit (on any day that the console is staffed) to the Payload Operations Director (POD) and the Payload Operations Manager (POM) had a place for “Forward Actions”, but the section was not well-defined. Other sections had been defined early in the ISS program, but hadn’t been validated and/or updated with respect to current operations. The scheme that evolved has these features:

- Since the DR is mandatory, we can guarantee that PAYCOM will open and look at it every day on console.
- New DRs are created via a “Save As” of the previous report. This eliminates errors from cutting and pasting from one console log entry to another.
- New or modified information is entered in blue text, and changed to black in the following report. Entries being closed are put back into blue text for their last appearance in the report. Authors and editors include date/initials on revisions.
- Separate sections exist for Actions (discrete tasks, usually of a one-time nature) and Reminders (tasks or things to remember tied to recurring events or circumstances, e.g. “gotchas”).
- The section originally titled Malfunctions and Recoveries now includes all Significant Events, including notable successes. Sections covering info that “belongs” to other teams have been eliminated.
- POD/POM are now aware of what we think is important, and can ask us to 1) delete items they’re working and/or 2) add items they’d like us to take on. “Trim the overlaps, fill in the underlaps.”

These modifications helped a great deal for day-to-day ops, but the question arose, “If someone asked us to account for all of our unique action items (e.g., those not covered in formal databases), could we summarize what they are/were, and how they were resolved?” Well, we could... but digging through all the DRs would take an incredibly long time, and one would have to sort through repetitive entries from the date an item appeared to the date it was removed. Someone suggested that we “roll off” the action items into a matrix for future reference, including start and stop dates to show the timeframe. We concluded that summarizing Reminders, Significant Events, and other Comments would also be useful. Due to the time pressures of operations, we update the matrix offline at intervals... more on this later.
Examples

Figure 1 shows the PAYCOM's usual interface to their console log database, and provides familiarization with the environment. Figure 2 presents a subset of log entries related to an Action that appears on the DR (Figure 3) and in the Rolloff Matrix (Figure 4). Explanatory notes are in text against a beige background, with purple lines/arrows as needed. The thrust of this paper is method, not ISS program content, so most acronyms are not defined.

As of October, 2007, the actual matrix of about 350 entries covered roughly 1.5 years of operations.

Customized layouts for various console positions (Positions each have their own database, but share a common file template and some linkage files)

Export Log creates HTML file of a day's log and emails to all PAYCOMs and the Realtime Information Control Office (RICO). RICO saves file as the official (Quality Record) archive for that day. [1]

Due to space limitations, this example shows only short entries selected from a single day. Emails, text from change requests, literal transcription of voice loop conversations, and complicated handover notes can be quite large. Entries shown here do not correspond to entries in the Daily Report and Rolloff Matrix examples.

Figure 1 – PAYCOM Log Format (Working Interface)
<table>
<thead>
<tr>
<th>YEAR</th>
<th>DOY</th>
<th>GMT</th>
<th>Loop</th>
<th>Controller</th>
<th>Log Entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>249</td>
<td>19:15:30</td>
<td>S/G 1</td>
<td>Shannon Rutherford</td>
<td>Greetings to and from Houston… We'll hand you over to Huntsville. PAYCOM-Good evening Fyodor, Oleg and Clay. We have one topic for Clay when he is ready. Clay-I'm ready. PC- Your EPO Kit C check activity is going to be removed from the timeline tomorrow. You will have one last photo session scheduled on Saturday and this will officially complete the 20 days of joint on-orbit and educational plant growth. And then we will give you friendly reminders every 5-6 days about watering the plants. Clay-okay. Let the PI know that I hope he gets good science and hopes the kids can learn from his experiments. Handover to Moscow.</td>
</tr>
<tr>
<td>2007</td>
<td>253</td>
<td>20:15:33</td>
<td></td>
<td>Bernd Billmeyer</td>
<td>EFN 22389 - POIC DAILY SUMMARY INPUTS for GMT 254 Payload Status: Clay: Today you will replace the EMCS Water Reservoirs to… Clay: Options for Saturday Science may be found in message 15-1164. Clay: This is your friendly 5 day reminder to check the EPO Kit-C plants. CEO targets are in message 15-1163. ( \ldots )</td>
</tr>
<tr>
<td>2007</td>
<td>254</td>
<td>6:03:13</td>
<td>over the wall</td>
<td>Don Reed</td>
<td>POD and OC let me know that I would have 1 mDPC topic this morning regarding the 5 day reminder to Clay to check the EPO Kit C Plants. PC copied and said that I would make sure I check in with them before I relay my topics to CC</td>
</tr>
<tr>
<td>2007</td>
<td>256</td>
<td>16:25:59</td>
<td>POD</td>
<td>Bernd Billmeyer</td>
<td>Notified POD that next EPO KIT-C reminder to crew is due GMT 259 (Sunday). There may be no PC staffing.</td>
</tr>
<tr>
<td>2007</td>
<td>260</td>
<td>13:32:45</td>
<td>OTW</td>
<td>Shannon Rutherford</td>
<td>OC informs us OTW that Clay no longer needs the 5 day remiders to water the EPO Kit C plants. OC took it as the plants were dying and that Clay wasn't going to mess with them any more. We can take this off of our carry overs. ( \text{mDPC topic - } &quot;\text{Clay, today is the day for your next 5-day EPO Kit C friendly reminder. You had mentioned that you may not need these anymore. If so, just let us know and we will stop reminding you. Please let us know if you need a pointer to the Kit C stow steps&quot;})</td>
</tr>
<tr>
<td>2007</td>
<td>264</td>
<td>6:55:48</td>
<td></td>
<td>Jessica Thompson</td>
<td>I have a few concerns about this topic. First - I need a reminder about the stow steps myself - which procedure, steps, etc. ( \ldots ) After research between POD, OC, and PAYCOM (me and Tameka) we haven't found much info about the stow. So, the new topic is: &quot;Clay, today is the day for your next 5 day EPO Kit C friendly reminder. You had mentioned before that you may not need these anymore, so if this is the case just let us know. We'll get together the stowage information for you.&quot;</td>
</tr>
<tr>
<td>2007</td>
<td>264</td>
<td>08:06:05</td>
<td>Email</td>
<td>Jessica Thompson</td>
<td>POD asked us to email EPO regarding EPO Kit C stow: 'Today during mDPC, we gave Clay his 5 day EPO Kit C reminder. We also told him that in the past he mentioned that he may not need these anymore and if this was the case then we would get the stowage information for him. Clay said he was ready for stowage information. We need to verify that he is to use 2.001 EPO Kit C operations procedure, all of step 3 and also where to stow. Are Big Picture Word still needed? This action was in our Daily Report for EPO to provide. Thanks for your Help - Jessica</td>
</tr>
<tr>
<td>2007</td>
<td>264</td>
<td>11:56:55</td>
<td>Handover</td>
<td>Jessica Thompson</td>
<td>Handover: ( \ldots **\text{We owe Clay EPO Kit C Stow information - see log entries 06:55, 07:54, and 08:06. Also see DR. }\ldots )</td>
</tr>
</tbody>
</table>

**This is in HTML Archive format discussed at top of Figure 1. Ellipses indicate removal of text blocks to save space.**

**Figure 2 – Selected Log Entries Related to Daily Report Example**
<table>
<thead>
<tr>
<th>Action Items</th>
<th>Action Items</th>
<th>Action Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>207/220</td>
<td>207/200</td>
<td>207/220</td>
</tr>
<tr>
<td>206/138</td>
<td>206/131</td>
<td>206/123</td>
</tr>
<tr>
<td>206/118</td>
<td>206/113</td>
<td>206/106</td>
</tr>
<tr>
<td>206/100</td>
<td>206/94</td>
<td>206/89</td>
</tr>
<tr>
<td>206/84</td>
<td>206/83</td>
<td>206/82</td>
</tr>
<tr>
<td>206/81</td>
<td>206/79</td>
<td>206/76</td>
</tr>
<tr>
<td>206/74</td>
<td>206/72</td>
<td>206/70</td>
</tr>
<tr>
<td>206/68</td>
<td>206/66</td>
<td>206/64</td>
</tr>
<tr>
<td>206/62</td>
<td>206/60</td>
<td>206/58</td>
</tr>
<tr>
<td>206/56</td>
<td>206/54</td>
<td>206/52</td>
</tr>
<tr>
<td>206/50</td>
<td>206/48</td>
<td>206/46</td>
</tr>
<tr>
<td>206/44</td>
<td>206/42</td>
<td>206/40</td>
</tr>
<tr>
<td>206/38</td>
<td>206/36</td>
<td>206/34</td>
</tr>
<tr>
<td>206/32</td>
<td>206/30</td>
<td>206/28</td>
</tr>
<tr>
<td>206/26</td>
<td>206/24</td>
<td>206/22</td>
</tr>
<tr>
<td>206/20</td>
<td>206/18</td>
<td>206/16</td>
</tr>
<tr>
<td>206/14</td>
<td>206/12</td>
<td>206/10</td>
</tr>
<tr>
<td>206/8</td>
<td>206/6</td>
<td>206/4</td>
</tr>
<tr>
<td>206/2</td>
<td>206/0</td>
<td></td>
</tr>
</tbody>
</table>

- **Action Items**
  - 207/220
  - 207/200
  - 207/220

- **Action Items**
  - 206/138
  - 206/131
  - 206/123

- **Action Items**
  - 206/118
  - 206/113
  - 206/106

- **Action Items**
  - 206/100
  - 206/94
  - 206/89

- **Action Items**
  - 206/84
  - 206/83
  - 206/82

- **Action Items**
  - 206/81
  - 206/79
  - 206/76

- **Action Items**
  - 206/74
  - 206/72
  - 206/70

- **Action Items**
  - 206/68
  - 206/66
  - 206/64

- **Action Items**
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  - 206/60
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- **Action Items**
  - 206/56
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- **Action Items**
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- **Action Items**
  - 206/44
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- **Action Items**
  - 206/38
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- **Action Items**
  - 206/32
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- **Action Items**
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- **Action Items**
  - 206/20
  - 206/18
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- **Action Items**
  - 206/14
  - 206/12
  - 206/10

- **Action Items**
  - 206/8
  - 206/6
  - 206/4

- **Action Items**
  - 206/2
  - 206/0
**DISCUSSION**

**General Discussion**

In the DR, content entries appear with bullet symbols under the appropriate heading. Visual organization, including header and content text color, is important for navigation and clarity. New and changed content are in blue text in the first report in which they appear. Text is changed to black for subsequent reports, then back to blue in the last report in which it appears. This makes it easy to see what is changing, and the “Opened Today” and “Closed Today” headings act as prompts for a) drafting the next day’s report (with a “Save As” command), and b) moving Actions and Reminders to the Rolloff Matrix.

Content in the DR should summarize each topic very briefly. Wholesale copying and pasting from detailed console log entries tends to clutter things up. Instead, a simple reference to “log DDD:hhhh” (DDD -> Day of year, hhh -> GMT 24-hour time) can guide the reader to in-depth information.

Some challenges encountered in preparing DRs include:

- Making sure Actions suggest what the console operator needs to do, not merely describe an issue or status.
- Obtaining consistency among operators, e.g., establishing what constitutes a Significant Event, when an action should be carried in the DR vs. handling it in handover notes within the console log.
- Keeping the entries brief. This was mentioned in a separate paragraph above. It’s important enough to emphasize again... and again.
- Following through on protocol for manipulating text – colors, moving, deleting. In some cases, especially during fast-paced operations, 2 or 3 days may elapse before the “right” thing happens to a block of text. However, this can be compensated for during Rolloff Matrix processing.

The Rolloff Matrix is essentially a collection of index tabs, so brevity is critical. Description and Disposition should be kept to 1-3 lines, 5 lines maximum. Start and stop dates tell the reader which DRs and/or console logs to examine for details, and of course the DR entries may point to specific log entries. Significant Events and Comments typically appear just once in the DR, so “Date Closed” for these is usually blank.

Formally speaking, “Facility” refers to a rack or collection of racks onboard ISS that hosts equipment for specific types of scientific investigations, and “Payload” refers to a specific experiment, whether the experiment uses a Facility or not. In addition to these meanings, the columns serve to group non-payload items into major categories and sub-categories.

In developing the Rolloff Matrix concept, there was much discussion as to when items should be transferred from the DR to the Matrix – when they start vs. when they’re finished, as part of the daily console-keeping routine vs. offline by an off-duty console operator, etc. Greater consistency has been achieved by updating or “auditing” the Matrix offline, processing several DRs in one sitting. This allows time and a relatively unstrained environment step back from the operations tempo, compare successive reports for progression and consistency, discern the essence of each entry, and clean up the wording and/or Start/Stop dates. It takes about 2 to 3 hours to process a month’s worth of DRs.

If one has a situation with round-the-clock staffing and a reasonable amount of low-pressure time on at least one shift, maintaining a Rolloff Matrix might be feasible on-console, but this is not workable for PAYCOM, and there’s much to be said for the “let it soak in” phenomenon intrinsic to processing the Matrix offline. If less than a month’s latency is desired, reports could be processed weekly.

Another challenge in Matrix development was the question of which items to transfer from DRs. Some items may appear trivial – for example, a reminder to issue a reminder to someone else. While that’s a “mere” administrative action, it’s still an action, and represents something we were concerned about enough to document. To prevent biases due to different operators’ perspectives, we transferred all Actions, Reminders, Significant Events, and Comments to the Matrix. Excel’s data sort options can be used post-transfer to focus on the reviewer’s area of interest.

As with many endeavours, the Rolloff Matrix isn’t perfect, but therein lies potential for raising questions that can improve operations. While populating the matrix, it’s useful to include comments about what’s in the matrix in red and within brackets. Such comments might flag data inconsistencies, suggest followup activity, or state insights gained while reviewing the information.

A recently conceived idea (October, 2007) is to allow and encourage off-duty console operators to send comments or observations (based on reading the daily console log or on meetings relevant to current ops) to the on-duty operator for inclusion in the DR (labeled as an outside comment), and eventual transfer to the Rolloff Matrix. If practiced in moderation, this could enhance corporate consciousness.

The DR helps track Actions to completion, gives visibility to recurring Reminders, and documents Significant Events and Comments as they occur. The Rolloff Matrix retrospectively synthesizes these and provides initial navigation for analyzing past operations or preparing for future ones.
Figure 5 summarizes how Console Log, Daily Report, and Rolloff Matrix entries inter-relate.

**Bonus: Checkbox Technique**

While writing this paper and contemplating the documents involved, an idea emerged that is tangential to the DR/Rolloff Matrix scheme yet relates to mission analysis. Figure 1 noted some checkboxes developed about 6 years ago that are not used much:

- Handover
- Exec Pkg Input
- Stowage
- DPC Input
- Word of the Day

In practice, we hardly ever pulled up all entries related to one these topics, and/or found other ways to identify them with text in the main text area. Suppose we used these topics to identify truly unique log entries:

- Bravo!
- Oops!
- Hmmm…
- HMI

The tempo of operations often doesn't provide the "soak time" needed to ponder how to repeat good things, reduce bad things, solve a mystery, or kindle a fire from the spark of an idea that flits across consciousness, but if we don't capture the sparks or seeds "in the moment", they're often lost. The short, casual titles are deliberate – our work is technical, but doesn't have to be cold.

HMI - Humor, Morale, or Insight. In addition to their intrinsic value to console operators, having a quick way to find H&M entries (and Bravos) could be used to find flavoring for many kinds of meetings, e.g., technical or programmatic forums, social or PAO visits by program participants, etc. Insight may pertain to processes, systems (technical or human), or other aspects of the operations environment, and is closely related to "Hmmm..." – "Hmmm..." is characteristic of a question, Insight is like an answer, though not necessarily to the same question. Some entries flagged by Checkboxes would generate entries...
in DRs and the Rolloff Matrix, such as an outstanding payload run (good or bad) or an idea for a new technique. Others would be highlighted only via checkbox, such as a pat on the back to a colleague or a humorous event.

The proposed Checkboxes honor the emotional aspects of realtime operations, something which is often unaccounted for but really needs to be harvested. With ISS, flight crews live “in the can” for six months. Ground controllers go to other places before and after their shifts, but live in the environment for years.

Using Checkboxes lacks the analytical depth of the DR/Rolloff Matrix scheme, but could be a valuable adjunct—a very quick map of peaks, valleys, and places to explore. Plus, being able to recall a chuckle or an inspiration now and then preserves sanity.

**CONCLUSIONS**

Including Actions and Reminders in a mandatory Daily Report ensures that:

The duty console operators for the team submitting the report view Actions and Reminders daily.

Ops management personnel receiving the report are aware of items being tracked, and can compare them to their notes to eliminate duplication of effort and/or fill in gaps appropriate to the function of the reporting console position.

Transferring Actions, Reminders, Significant Events, and Comments from the Daily Report (DR) to a Rolloff Matrix provides a categorized synopsis of issues and events that have risen above the noise level. The transfer is best accomplished in an offline mode, e.g., by an off-duty console operator processing a week or a month of Daily Reports in one sitting of 30 minutes to 3 hours. Visual layout and color-coding within the Daily Report make preparing the report and transferring data to the matrix easier.

Information contained in the Rolloff Matrix has several uses:

Prepare to operate a given payload. Check its history for trends, issues, and/or “gotchas”. Start/stop dates and/or console log references (in Matrix or Daily Report entries) provide quick navigation to supporting details.

At the beginning of a payload increment, determine which Reminders to continue, discontinue, or resurrect.

At the end of an increment, identify lessons learned. (Two mechanisms are at work here. If a lesson is recognized at the time something happens, it can be put in the DR and hence the matrix, for ready recall later, as opposed to getting buried so deep in a console log that it’s not recalled months later. If a lesson is not noticed in the moment, it may be distilled in the process of reviewing all the items that rose above the noise.)

Derive questions (or answers) for mission briefs or debriefs. Identify topics for “go-back” discussions and/or further research.

Demonstrate thorough accountability and/or traceability of action items not covered in formal databases.

Gain insight about and improve consistency of console operations themselves. Examples of things to look at: Types of actions tracked, and how long they’re typically carried; When an item is complete as opposed to when it’s actually removed from the DR. Consistency of what different operators include in the DR.

Future uses for the Rolloff Matrix could include being a starting and/or orientation point for in-depth analysis of a given payload or facility, or being used to guide team discussions of an analytical or training nature.

Generically, post-ops and/or in-ops analysis for long-term operations can be significantly enhanced by having a daily means of capturing actions and “above the noise” issues that are not covered by primary ops databases, first because they are actions or are above the noise in their own right, and just as importantly because trends may develop over time that provide useful insight. Performing the capture via a report viewed by others enables feedback, validation, and reduction of gaps and/or overlaps.

Routine harvesting of Daily Report data into a Rolloff Matrix summarizes and indexes the actions and issues so that they are not lost in the abyss of a comprehensive console log or hidden in reams of daily reports.

Creative use of Checkboxes in an electronic console log can provide quick access to entries on topics of particular interest, especially “softer” yet incredibly valuable aspects of long-term operations, and may be a valuable adjunct to, though not a replacement for, the multi-threaded analysis made possible by a Rolloff Matrix.
REFERENCES


BIOGRAPHY

David W. Scott, alias “Scotty”, has been a Payload Communications Manager for the International Space Station since 1999, and is also involved with training and operations development for NASA’s next-generation ARES launch vehicles. He’s spearheaded several console technology projects, especially in space-to-ground videoconferencing and audio archiving. He was a payload communicator for the ATLAS-1 Spacelab mission in 1992, and helped design the payload training program for Space Station. He spent 6 years as a U.S. Naval Officer, including flight duty in F-14s, and holds a B.S. in Physics and Mathematics from Principia College.