An Adjusted Reliability Model for HST Science Operations
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In response to a request from the Bahcall Committee, the HST Program has worked with The Aerospace Corporation to create and run an adjusted version of the model described in "Hubble Space Telescope Reliability Assessment, July 2002 Model" [Aerospace Report No. TOR-2003(2154)-2352]. The results of that model are available to the Committee in the HST Project's fact sheet entitled "Expected HST Lifetime after SM4." The adjustments have been made to provide a less-constrained assessment of likely HST lifetime after SM4.

As noted in the above-mentioned fact sheet, the baseline HST Reliability Model is a conservative model. It is built from a description of the relationships of the various HST subsystems and the redundancy available within the subsystems, and from the subsystem requirements for nominal operation of HST (i.e., as it is operated today). It uses box-level failure rates revised via application of a generally accepted technique to incorporate flight experience. The original failure rates themselves are the results of standard reliability calculations.

In particular, three features of the baseline HST model result in a conservative prediction:

1. It makes no allowance for operational workarounds and accommodations that might ameliorate loss of a failed "box" and permit continuation of high-value science
2. It uses box-level failures rates that, though adjusted for in-flight use, predict more problems in some cases than our own experience with HST indicates
3. It makes no allowance for internal component failures that might render a "box" less than fully functional, but still permit its use in HST science operations.

In summary, the baseline model serves a purpose similar to the original pre-launch model upon which it is based: it provides a guideline for planning HST Servicing Missions (SMs) at intervals that largely assure the continued (and uninterrupted) productivity of the Observatory. As seen in the original report, it is also used to evaluate the gain in overall reliability of proposed servicing improvements, such as the Data Management Unit (DMU)-to-Science Instrument Command and Data Handler (SI C&DH) Cross-strap Unit (DSC) in SM4.

The Committee has invited us to use the HST Reliability Model for a different purpose: namely, as an indicator of the time-dependent prospect for continuing a scientifically productive mission after the final HST SM. In response we have made some adjustments to the model and its input data that address the first two features identified above. We have done nothing to adjust the model for "friendly" failures that eliminate some aspects of a box's functionality but do not remove a piece of hardware from service. We do not know how to do that in a simple, yet defensible, quantitative way.

To address the first-listed feature of model conservatism we have incorporated five changes that assume the availability of failure workarounds or related enhancements. For each, we either have an implementation plan, or we have enough knowledge to be confident about feasibility and value.

The five changes incorporated in the adjusted model are:

1. Continued operations in Two-Gyro Science (TGS) Mode
2. Continued operations if only one Fine Guidance Sensor (FGS) remains
3. Continued operations if only one Fixed Head Star Tracker (FHST) remains
4. Installation of the DSC
5. Continued operations without Solar Array Drive Electronics (SADE)

In each case, the corollary hardware requirements for workaround modes (e.g., TGS Mode requires two FGSs and two FHSTs) have been made part of the model. [Note also that the minimum requirements for the first three items differ; e.g., workaround #3 requires three gyros.]

To adjust the second feature of the present model's conservatism we have altered the failure rates of five HST subsystems or their components. In each of these cases, the reliability of the HST hardware has significantly exceeded that predicted by the use-adjusted computed failure rate for the item. In these cases one has to ask, "Have we been lucky, or was the original failure rate overly pessimistic?" For example, the Bayesian-adjusted failure rate for the FGS/Fine Guidance Electronics (FGS/FGE) subsystem yields only a six percent probability of our having experienced no subsystem failures in more than 13 years of flight operations. It is much more likely that in this case the real failure rate is actually lower than that predicted from the pre-launch models, adjusted by the Bayesian technique.

For the adjusted model we have modified the failure rates for five such elements within HST. The criterion for each new failure rate is that it yields a 50% probability of our having experienced no failures during the hours of use of that subsystem or component between HST's launch and 8/1/03. These substitute failure rates are chosen such that our experience with the each of the five elements has been neither lucky nor unlucky.

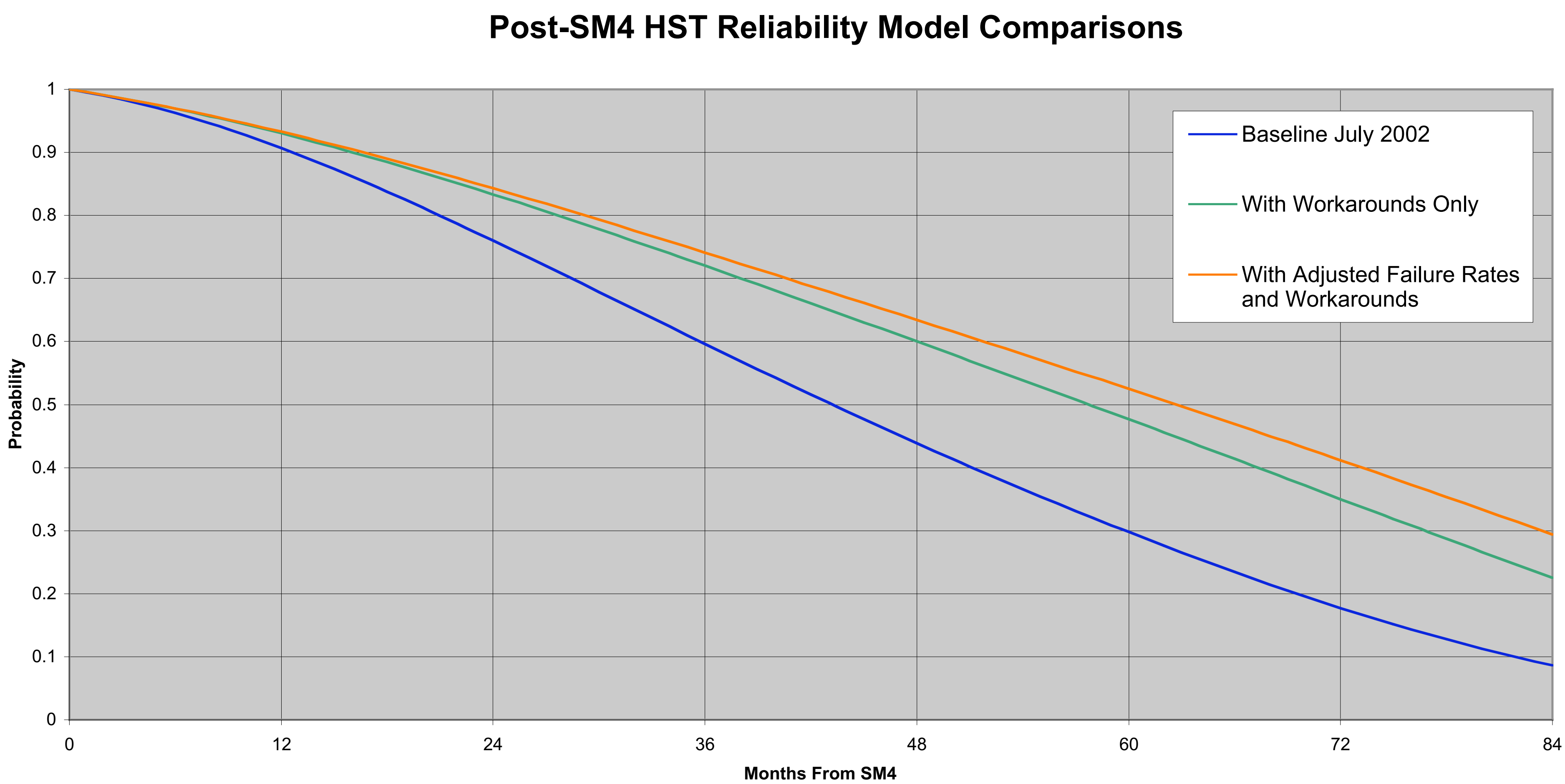
The five HST elements with failure rates adjusted in this way are: the FGS/FGE pairs, the FHSTs, the Multiple-Access Transponders, the SI C&DH Memory Modules, and the redundant sides of the DMU.

The gyro reliability model and the science instrument failure rates are unchanged.

The failure rates of all other components of the model have been adjusted by Bayesian analysis for their additional hours of use between 6/30/02 and 7/31/03.

The adjusted model provides a less pessimistic, defensibly reasonable prediction for the probability of continued HST science operations over time, and still retains some innate conservatism. We have neither attempted to identify nor include an exhaustive list of potential failure workarounds. We have limited our failure rate adjustments to "tall pole" items with excellent performance records. We have not adjusted for benign failures that permit a box's continued use. We have retained our conservative estimate of the improvement in gyro lifetime afforded by silver-plated, a.k.a., "enhanced" flex leads.

The adjusted model predicts that the probability of a productive science mission continuing for 5 years after SM4 is ~50%. The probability of six years of operations after SM4 is ~40%. (Lacking these adjustments, the July, 2002 baseline model predicted 30% at 5 years and 18% at 6 years.) **Stated another way, the relaxed assumptions lead to an expectation of an additional one to two years of science operations.**


Post-SM4 HST Reliability Model Comparisons
Probability
Months From SM4
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
12
24
36
48
60
72
84
Baseline July 2002
With Workarounds Only
With Adjusted Failure Rates and Workarounds