Faster, Better, Cheaper: Embracing The Sequel?

In the 1990s, NASA's Faster, Better, Cheaper (FBC) mantra almost drove the U.S. robotic Mars exploration program into oblivion. It seems optimizing the aerospace trade space between schedule, quality, and cost always requires a dynamic equilibrium between these attributes, typically with razor-thin stability margins. Performing this unnatural balancing act over protracted time intervals, human nature gives rise to a culture in which deviance becomes normalized to the point "dodging bullets" and Russian roulette become routine practice. Sooner or later, this unwitting pattern of risk acceptance results in disaster. Following loss of the robotic explorers *Mars Climate Orbiter* and *Mars Polar Lander* within about 10 weeks of each other in 1999, it became lore among aerospace workers that expecting to maximize more than two attributes in the FBC trade space is unrealistic, even delusional.

A similar lesson has been learned time and again in U.S. human space flight (HSF). During a schedule-driven Apollo Program virtually free from cost constraints, the watchword was "waste anything but time". Particularly after the Apollo 1 fire claiming the lives of astronauts Grissom, White, and Chaffee in 1967 and the ensuing 18-month flight operations stand-down, it became abundantly clear that satisfying a schedule to achieve HSF's first lunar landing before 1970 entailed maintaining quality at any cost. Investigations of the *Challenger* (1986) and *Columbia* (2003) Space Shuttle disasters have identified as one root cause a culture permitting cost and schedule pressures to compromise quality.

Because lives are at stake, HSF demands uncompromising dedication to sufficient quality, leaving only cost and schedule to be traded. Furthermore, as we look beyond low Earth orbit to humans exploring interplanetary space, the level of minimally acceptable quality must only increase to accommodate harsher environments, increased performance demands, and independence from Earth (other than high-latency communications) for months or years.

Why then does hardly a month go by without a report, workshop, or conference calling for humans on the surface of Mars in the 2030s? These calls further maintain the feat is "affordable" and can be accomplished with only modest increases to current NASA funding. The trick, some claim, is to repurpose ISS funding following its projected retirement circa 2024. But this is a celestial shell game. The cost of current "assembly complete" ISS operations and logistics pales in comparison to assembling and outfitting spacecraft to enable a human roundtrip to the surface of Mars. As became apparent during Space Shuttle retirement, some costs associated with large NASA programs remain after program termination. Much of today's ISS budget will continue to be claimed by ongoing ground-based infrastructure maintenance costs and compensation for retained personnel after 2024.

Today's FBC Mars HSF mission concepts strain cost and schedule to the point quality will be compromised and astronaut lives will be lost. When these deaths are investigated, findings will impose a delay in Mars flight operations while quality deficiencies are corrected at great expense. Would it not be more ethical to simply achieve this level of quality first and ignore whether or not humans reach the surface of Mars before 2040?

A great deal of Mars exploration can be done through low-latency telepresence (LLT) with humans in Mars orbit and robotic systems on the surface. Starting in 2014, NASA's Evolvable Mars Campaign has acknowledged the potential for LLT from Mars orbit to enable Mars exploration. Such LLT-enabled exploration can be performed sooner, with less risk, and for lower cost than landing humans on Mars. Although this sounds like FBC, recall LLT-focused missions require HSF proceed only as far as Mars orbit, postponing arguably the most expensive and hazardous legs of a Mars surface roundtrip. During the LLT phase of Mars exploration, infrastructure facilitating human landings on Mars can also be established in orbit and on the martian surface. Furthermore, any extant native life will be far better insulated from human contamination during LLT operations than premature HSF landings permit. Would it not be in the interest of astrobiology to postpone such contamination until we are more certain Mars is a sterile world, even if HSF landings there are delayed beyond 2040?

For those desiring a sustained, perhaps colonial, human presence on Mars, initiating that presence with a cost-constrained landing in the 2030s might be a very poor strategy. This decade features some of the least demanding opportunities to reach Mars and return to Earth this century because propulsion and estimated radiation shielding requirements are minimal. Designing HSF architecture to these best cases might then result in a one-off capability and outright cancellation if cost pressures mount from overruns or another economic downturn.

Review of the *Report of the Second Mars Affordability and Sustainability Workshop* published early in 2015 by Explore Mars, Inc.[*] has captured multiple examples of unrestrained FBC thinking in a proposed headlong rush to place humans on Mars in the 2030s. The report's findings and recommendations are not well substantiated, and conclusions termed "consensus" among workshop participants are contradicted elsewhere in the report. A more measured pace for Mars exploration utilizing LLT is rejected because participants did not find it to be an accepted best practice in space exploration. Given there is no experience base with which to establish best practices for human Mars exploration, this rejection has no rational basis. Rejecting LLT also ignores currently operational LLT capabilities in the fields of mining, undersea operations, warfare, and surgery on planet Earth.

Those claiming human Mars exploration is affordable and sustainable could bolster their credibility by estimating the enhanced probability of an astronaut's death from cancer after having flown a mission to Mars with the associated architecture. Stakeholders could then trade this risk against the maximum 3% enhanced probability of cancer death permitted for ISS astronauts, atomic energy workers, and radiologists (reference "Radiation Risk Acceptability and Limitations" by Francis Cucinotta, Ph.D[†]). Some FBC architectures are estimated to impart a 30% enhanced cancer risk. If so, what on Mars impels human exploration that is 10 times more urgent than keeping earthlings supplied with electric power and medical services? Can we really afford to sacrifice the best among us to FBC Mars exploration? Clearly, more robotic Mars exploration is necessary to discover the "unobtainium" or native life forms justifying this level of HSF risk-taking. Otherwise, the first human landing on Mars, an undeniable milestone in human history, will be ethically unsustainable.

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[*] This report can be downloaded from http://www.exploremars.org/wp-content/uploads/2015/02/Affording-Mars-2014-Report_1-2.pdf (accessed 13 May 2015).

[†] This paper can be downloaded from http://three.usra.edu/articles/AstronautRadLimitsFC.pdf (accessed 20 May 2015).

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Nearly two generations after the first HSF lunar landing, those of us who began our aerospace careers at the dawn of the Space Age are getting long in the tooth. We hunger to surpass the accomplishments of 50 years ago and broaden humankind's horizons. As keepers of Apollo's legacy, however, we must remain responsible and temper FBC delusions with hard-won experience. Younger aerospace workers and policymakers should turn a wary eye toward the Captain Ahabs among us beckoning them on to Mars at any cost.