A Few Thoughts on the Wisdom of Systematic and Consistent Funding of Technology Development for Larger Missions

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Abstract:

We present some of our thoughts on the importance of consistent technology development funding for large NASA missions in the context of maximizing the return on investment to the American taxpayer.

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This short Technology White Paper is intended as a modest contribution to the understanding and communication of the appropriate balance between focused initiatives and general technology development.

Large NASA missions such as HST, Chandra, JWST, the Mars Science Laboratory, IXO, LISA, etc., frequently require significant technology development (TD) in order to meet performance requirements derived from Science Goals. New technologies for NASA missions might start as non-mission-specific ideas in the broader science, technology, engineering and mathematics community and later be adapted for a mission, or as an idea posed to solve a mission-specific problem. In any case, once a particular technology has been identified as a potential candidate for a large mission, its development often takes place over a long period of time (more than ten years is not uncommon) before the mission enters Phase A.

During this long period NASA's commitment to a specific mission is often subject to strong fluctuations, which typically leads to strong variations in the generally low level of funding available for TD. The main point of this paper is that TD funding levels that are too low and too volatile can be highly detrimental to the achievement of scientific AND BUDGETARY mission goals. We motivate our point with the following:

I. The Importance of University-Based Technology Development

Mankind's rapid increase in knowledge and technical capabilities creates breathtaking opportunities for advancement in space instrumentation, but at the same time poses enormous budgetary and programmatic risks. These risks are strongly amplified by insufficient and fluctuating TD funding. Missions which require 10-20 years of gestation require a dedicated cadre of scientific and technical boosters who are willing to go the distance. NASA relies strongly on the academic community for this vital resource. Boosters are placed in the double-bind of having to sell their mission concepts as scientifically exciting, which tends to push the state of the art, and at the same time as low risk and "ready-to-go," which tends to restrict technology development to "safe" solutions with short time horizons. This environment creates powerful incentives for TRL inflation, especially between teams supporting competing mission concepts.

Systematic, well-reasoned, and early support of TD, especially in the academic sector, has the potential to significantly reduce these factors which are tending to boost mission risks and costs. Universities can provide patient, thorough, academically rigorous, and peer-reviewed scientific and engineering development which is essential to ensure that advanced technology which proceeds to mission development has been thoroughly understood and optimized. Perhaps even more importantly, this environment can provide thorough analysis of concepts that DON'T turn out to work. These insights come dirt cheap during the early stages of a mission, but very dear indeed at the peak of funding. As an important by-product of this approach, energetic young scientists and engineers are trained which are the life-blood of NASA's and our nation's future, and incentives are created for retaining talented senior researchers in the space instrumentation business, which frankly has few other rewards.

Unfortunately, the current NASA funding environment does a rather poor job of fostering a supportive university TD environment. The available funding is generally inadequate, sometimes grossly so, to meet the basic needs of university laboratories. Development of advanced space instrumentation requires advanced facilities and talented, full-time professionals. Funds through the ROSES program, while appreciated, are so meager and oversubscribed that they can generally support only very modest efforts. In our experience, funding through mission project offices (when it is available) is biased towards NASA centers and tends to be driven by short term, task-oriented considerations which view graduate students simply as labor costs rather than assets. Graduate fellowships targeted to university instrumentation development appear to be non-existent.

II. Fluctuating Funding is Wasteful

TD requires investment in infrastructure and hardware as well as in qualified people. When funding is relatively plentiful these investments are often happily made. TD for large NASA Science Missions is performed in large measure by professional scientists and engineers (PSE's), including graduate students – often at the direction of tenured faculty at US colleges and universities – and these are the people who are hired during "good" TD times rather than faculty. However, when funding gets cut significantly over a longer time (a year is sometimes enough), PSE's are also the first to lose their jobs. The predictable outcome is that they will look for work elsewhere, and with them goes a large part of their TD expertise. Even if a year or two later funding looks great again, new people will have to be hired and to be trained again at great expense of time and effort. One can make a similar argument for infrastructure investments (such as custom-built metrology equipment, experimental setups, etc.), which can decay rather quickly when not used and taken care of, and for which new users have to be hired and trained after a period of cuts.

It therefore seems obvious that a TD effort that receives a fairly constant or slowly varying level of funding will be more cost-efficient and productive than an effort with the same average funding that fluctuates strongly over the same length of time.

III. Paying for Your Youthful Sins Later

NASA has garnered a bad reputation for project delays and budget overruns. The American taxpayer has a rapidly decreasing tolerance for failure and cost overruns due to lack of technical excellence. We believe that a commitment to steady TD support at an appropriate funding level can help reduce the length of delays and the amount of cost overruns. Figure 1 shows an imaginary funding curve or cost profile for a large, multi-billion dollar mission. It begins with a long period of mission concept and technology development at a relatively modest level. Ideally we would like this part of the curve to be relatively smooth and probably slowly rising. This is the time when a lot of deliberate and deep thinking can go into the development of a mission, and when errors are relatively cheap and inconsequential. According to our thesis the productivity of this period will suffer if funding fluctuates as indicated. So either the beginning of Phase A will be delayed in order to make up for less-than-ideal TD results, or the mission enters Phase A as planned. Once the mission ramps up into increasingly costly Phases A-D, any problems or mistakes that lead to delays can easily be ten times more expensive than similar delays or missteps during the TD phase. On top of that will be the cost of potential solutions to the delay, since now the highest priority will be to find the fastest solution to the problem, and not necessarily the smartest, most effective, or scientifically most prudent solution, since there is no time to move beyond whatever can solve the delay quickly. This can result in further cost increases, as well as in scientifically regrettable solutions (i.e., acceptance of lower performance, removal of an entire instrument/experiment, or even mission cancellation).

Simply put, a six-month delay during TR might cost an extra $5M, while it might cost an extra $150M during Phase D. And the first case might result in a better mission as well.

We have presented our thoughts on this subject in a highly simplified and schematic form to make our point, and we acknowledge that reality is certainly more complex than our argument. But perhaps this paper can be the impetus for NASA to look into its past and current experiences to see if our argument holds water. If so, it might lead the agency to reconsider future drastic funding cuts to ongoing TD efforts that are caused by unrelated events or financial pressures from other parts of the NASA budget.

We would like to make two specific recommendations as means to improving the situation. First, that funds for university research (e.g., through ROSES) should be boosted by a large factor, and that NASA publicly make protecting and sustaining these funds a corollary of its mission statement. This is likely to be painful to NASA in the short term, but in the long term will reap significant cost and risk reductions to the American public. It should be clear that the purpose of these increased funds is to decrease the cost of space exploration to the American taxpayer, create jobs and boost the US economy, and not for altruistic reasons tied to exploring the Universe. Secondly, we recommend that NASA create an opportunity for significant numbers of fully-funded graduate fellowships which are specifically targeted to university research and development of space instrumentation.

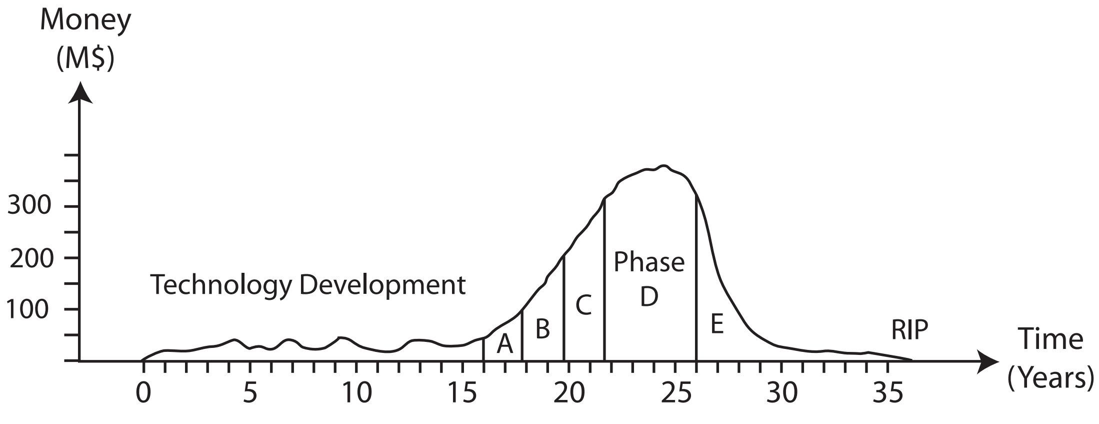

Figure 1: Annual funding profile for an imaginary large mission.