Deriving Technology Needs
From Measurement Strategies

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Abstract—The Earth-Sun System Division in the Science Missions Directorate of NASA has seven science focus areas, which are oriented to gathering space-based data used in the decision-making process for National policy on the Earth environment. Science roadmaps, derived from the NASA strategic planning process, serve as the vehicle for deriving measurement strategies and remote sensing requirements. The technology requirements (instrument, information systems, and platform) are developed to fit the schedule and cost assessed against the proposed mission need dates. This paper1 will discuss2 and show the current state of this process.

1. SCIENCE ROADMAPS

The Earth-Sun Systems Technology Office (ESTO) works with each of the Program Scientists in the Earth-Sun System Division to develop technology needs in support of future near-term (today-2015) and far-term (2016-2035) mission needs[3]. The 7 science focus areas are:

- Atmospheric Composition
- Carbon Cycle & Ecosystems
- Climate
- Earth Surface & Interior
- Sun-Earth Connection (currently Sun-Solar System Connection)
- Water & Energy Cycle
- Weather

In this paper these focus areas will be addressed in appropriate examples to show the technology development process used to translate science mission needs into measurement strategies and finally into candidate technology options. The science roadmap is derived from the Agency strategic planning process. It is the tool used to support the science community needs from NASA as well as the budgeting process baseline. Figures 1-7 show the current science roadmaps.

Figure 1 - Atmospheric Composition Science Roadmap

1 U.S. Government work not protected by U.S. copyright.
2 IEEEAC Panel 14.08, paper #2, Version 3, Updated January 27, 2005

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Figure 5 is a complete document[4] published in a pre-Agency transformation Office of Space Science.

Although the presentation of the science roadmaps differs minimally, the layout tells many stories all on one page. The purpose of these roadmaps restricts their planning to the near-term (today to 2015) timeframe as viewed along the bottom of the page. The science questions to be answered are addressed in the green or blue background area,
Figure 7 - Weather Science Roadmap

while the candidate mission needs are shown by the shaded arrows to the left of the green/blue fields. Of particular note for the purposes of this paper is the ‘T’ preceding some of the candidate mission arrows. These are the areas where technology development is perceived to be required in order to achieve the science measurements needed to fulfill the mission science.

A different formatting of the science questions into a summary chart for near and far-term mission planning proved to be useful in fulfilling our far-term technology development needs. A sample from one of the pages of the Carbon Cycle & Ecosystems focus area is shown in Figure 8.

Figure 8 - Sample Near/Far Term Measurement Needs

Figure 8 shows the science question down the ordinate in the green field (column) to the left. The central column defines the ‘New Measurements & Activities’ to address a particular scientific outcome, e.g. Physiology & Functional Types which has a near-term mission need in 2011, but a follow-on far-term technology development effort beyond 2016[3].

The science roadmaps and the measurement/mission needs derived charts provide the basis for discussing the details of the new science measurement strategies required to fulfill the science requirements in the near and far-term technology development planning.

2. TRANSLATING MEASUREMENTS

Determining the need for new measurement strategies from the existing science roadmap technology development requirements occurs via two primary vehicles. ESTIPS (the Earth Science Technology Integrated Planning System can be found at http://estips.esfc.nasa.gov). This system was developed several years back to support the existing NASA Earth Science Enterprise in translating science questions and measurements into new measurement scenarios and their associated technology requirements. Figure 9 shows an example from the Carbon Cycle & Ecosystems database on ESTIPS[2].
Figures 10 - Measurement To Technology

The Physiology & Functional Types measurement can be accomplished by two candidate technology options, one involving a differential absorption LIDAR instrument. As a one-page summary, the technology challenges shown to the right of UV/VIS DIAL are developed, in part, by the ESTIPS technology option on LIDAR in Figure 11.

Figures 11 - ESTIPS Technology Option Sample

Since this is a sample of the kinds of information available in the ESTIPS requirements database, it should not be taken as the de facto level of detail, since the teams of scientists and engineers involved in filling in this data have provided more or less based on the complexity of the technology option.

Once the strategic science measurement has been translated into a technology option(s), it is time to iterate with the science team in the focus area, and to develop a high-level product for summarizing the potential results.

3. CONCURRENCE CHALLENGES

The concurrence process is aided by a quad chart that is prepared for each of the candidate new measurements/missions appropriate to a specific science focus area [3].

Figure 12 shows a summary of the Photosynthetic Efficiency mission, a far-term mission in support of the Carbon Cycle & Ecosystems focus area.

Figures 12 - Quad Chart Sample For Concurrency

This quad identifies the far-term measurement/mission is the particular science focus area. Four sectors, Science Objective, Mission Description, Measurement Strategy, and Technology Requirements are used to tie this quad to the previously addressed science question/outcome chart in Figure 8. Every possible attempt is made to keep the specific technology candidates neutral in addressing the Technology Requirements block.

4. TECHNOLOGY OPTIONS PROCESS

Once the science focus area teams have converged on near and/or far term technology requirements, the ESTO technology development manager for the focus area team goes to work setting up technology options to meet the science mission needs. Each science focus area, we have found, chooses to present their approach differently, although we originally evolved a commonality in ESTO. This commonality was then tailored in regular discussions with the program scientists and their science team to meet the objectives they wish to portray for future missions.
Figures 13 - 19 show samples from each of six focus areas on how they portrayed the technology options for a specific science measurement/mission.

Figure 13 - Atmospheric Composition Technology

Figure 14 - Climate Technology

Figure 15 - Earth's Surface & Interior

Figure 16 - Sun-Earth Connection Technology

Figure 17 - Water & Energy Cycle Technology
The Physiology & Functional Types mission technology options shown in Figure 19 will be a good example for showing the product evolved by this process.

As in the science roadmaps, the bottom yellow horizontal bar reflects the timeline for this near-term “mission need.” Additionally, and only implemented currently by this science focus area, are a series of science milestones in cartoons. These will be used to assess progress of the technology development, trade-offs if a flight-of-opportunity should arise, and a vehicle to assist in focusing the instrument technology development effort.

The ordinate (Technology Options) moving to the right show first a green shaded area which has the heritage of instrument technologies that follow. Blue shows “challenging option(s)” which usually will be used in the far-term mission since substantive work/costs would generally not make it ready for the science “mission need” date, in this case 2011. The brown instrument option(s), 2 shown, are likely technologies to invest in for fulfilling the near-term science mission.

Along the top and (sometimes bottom) of a horizontal blue or brown bar, are a few key component technology challenges to be met roughly correlated to the timeline and the science milestones. Quantitative objectives are the goal, so some of these will change as the development effort and the science assessment progress. As an example, the DIAL instrument needs on-board Lossless data compression 3:1 in support of the Photosynthetic Efficiency far-term mission (see Figures 8, 12) since it is unlikely that the induced fluorescence LIDAR will be an available technology for the 2011 “mission need” date.

As can be seen by the varied approaches to refining the style of presentation, all of the science focus areas have tailored a basic concept to meet their particular needs.

5. CONCLUSIONS/NEXT STEP

Moving a science requirement to a science mission is a long process when there is a technology development requirement. It is not easy, as those who have been there and done that, know, to get a handle on the near-term, let alone the far-term science measurement/mission needs. It is more difficult to translate and separate the science objectives/questions/measurements from the implementation details of the technology development and engineering.

It is truly a team effort and at NASA we have found that the technology development managers often need to put up a notional concept for the science team to refine and fashion into a credible, do-able pathway to success.

As we transform the Agency toward exploration of the moon, mars, and beyond, a succinctly stated roadmap to developing mission-level technologies will provide a measurable schedule for assessing the readiness for a particular technology and the mission-start criteria for a science measurement mission.
REFERENCES


BIOGRAPHY

William Stabnow is a Technology Development Manager for NASA. He is responsible for the development of component and instrument technologies in support of the NASA/Science Missions Directorate. He supports the Agency Program Scientist, responsible for the Carbon Cycle & Ecosystems focus area, in identifying, planning, and scheduling strategic technologies in support of future Agency missions. He has worked for the Department of Army, the National Institutes of Health, and the Federal Trade Commission during his federal service career. He also taught physics and chemistry in the State of Montana. He has a BS from the University of Maryland in Chemistry.