Technology Area 12 Materials, Structures, Mechanical Systems, and Manufacturing Roadmap

A few thoughts

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Why me?

- Currently position: Technology Transitions Director, Program Manager for Novaworks, a rag-tag, fugitive few people developing innovative prototype solutions to a variety of problems

- 15 years experience at TRW/Northrop Grumman covering structures, materials, deployables, systems engineering, technology development, and program management. A few highlights:
  - Demonstrated thin-film bidirectional shape memory actuation control of membranes for large apertures
  - Demonstrated electrostatic control of membrane surfaces using Astromesh antenna technology
  - Led the development and demonstration of 30-meter composite deployable boom technology
  - Led development of critical pointing analysis and novel 1-g alignment of Astrolink Antenna payload
  - Developed key membrane technologies for enabling deployable systems
  - Principal Investigator – DARPA Reconfigurable Space Systems Study
  - Principal Investigator – DARPA Fractionated Spacecraft Architecture Study
  - Program Manager – DARPA F6 Program, DARC

Why me, part 2…

- 2 Patents in smart structures, 2 pending on novel space architectures
- PhD in Aeronautical and Astronautical Engineering, with a focus on analytical tools to analyze flaw behavior in coupled-field materials (piezo ceramics)
- Lecturer, UCLA/USC for Finite Element Analysis and Space Mission Engineering
- Member of AIAA Structures, Emerging Technologies, and Gossamer Program Committees
- Firm believer in the need for change in a struggling space industry
- Because I said “yes”

Technology Roadmap Overall Comments (1)

- With such mounting cost pressures on NASA and the nation, I expected to see an overriding theme that emphasizes lower cost technologies, such as is being done with the Chief Engineer of the Air Force.
  - While this roadmap addresses costs in a qualitative sense (‘cost effective certification Methods’ etc..) it would be preferable to have some quantitative cost savings included in the road map.
  - Some specific cost goals would be effective. Are we looking for increased capabilities for flat costs? Or sustained capabilities for reduced costs? Or new capabilities at the expense of old? How much cost reduction is enabled by which investment? Are we aiming to reduce development costs? Production? Operations?
- To assist in some focus on cost and accountability, it might be helpful to show entry points or ghost technology being done by other agencies (Air Force, NRO, DARPA, Army, etc.) to show NASA is not duplicating other US government investments, or conversely that the technology investments are leveragable across more than one agency

Technology Roadmap Overall Comments (2)

- Moreover, affordability is not the same as cost. Cost is a matter of magnitude, while affordability is a function of the required funding profile of a given technology.
  - Table 21. WBS # 2.4.4 ‘Sustainable Manufacturing’ starts to address affordability with ‘Affordability-driven Technologies - New and substitute environmentally sustainable processes’ but then goes on to only address environmental rather than affordability issues.

- In short, this roadmap does a good job laying out where we are going but needs to better quantify why we are going this way. It would benefit from some analysis of cost and utility where affordability is a measure of utility for Structures, Mechanical Systems, and Manufacturing investments being made by NASA on behalf of the taxpayers

Technology Roadmap Overall Comments (3)

- The roadmaps that show “push” and “pull” technologies are the most compelling and provides the most useful view into the overall picture
  - Linkage to other technical areas and other customers by notation would make this even better
- However, many of the roadmaps are very ambitious by way of developments
  - Clearly will require unlikely budgets to achieve without some significant change in the industry as we know it
  - Although there is an appreciation of the breadth of scope, the roadmaps appear to be an approach of listing anything and everything that can be thought of, as opposed to a few that are genuinely strategic and achievable (in time, cost, etc)
  - The roadmaps seem to stress quantity of topics (comprehensiveness) over quality and relevance of topic
- Different WBS elements seem to mention similar topics, so an underlying concern that research efforts could be duplicated (e.g. 2.3.1 Large Lightweight Stiff Deployable vs. 2.2.1 Expandable Structures)

Technology Roadmap TA12 Overall Comments (1)

- No discussion of Digital Direct Manufacturing in the actual roadmaps, although it seems to be addressed in 1.2 (as cyber-physical approaches) – which is currently resulting in much faster, lower cost parts with better material properties (metals and plastics), which is expected to have huge impact to future spacecraft, payloads.
- No mention of nano-resins for composites in these roadmaps – which are showing a 50-60% improvement in composite compressive properties
- No mention of carbon nanotube technology and its impact on composite properties or models – conductivity, damping, permeability, etc. – even if this mention is only to relate to the Nanotechnology roadmap.
- Roadmap shows solar sails in 2020? Is that for a specific size? They are flying now successfully in small scale.

Technology Roadmap TA12 Overall Comments (2)

- The Virtual Digital Fleet Leader is identified as the ultimate end goal in all the roadmaps.
  - What specific value is estimated to be brought forward with it (investment vs. use)?
  - A significant amount of testing will be required to validate such a model. Materials and structures in general have poor validation for space systems due to the lack of on-orbit data collection for materials, structures, etc. The "Test Tools and Methods" seems to address this at a cursory level, but not at a level that is actionable.
  - Could the implementation of well-understood modular (cellular) elements with simple inter-operational rules make this easier to develop or obviate some of the needs?
  - The focus seems to be on predictive behavior for reliability and safety, but having the data to enable such a tool would be able to design structures and deployables differently using inherent behaviors

Top Technical Challenges in Structures

- Mass-producible, modular integrated structures
  - Mass producible: production of these identical elements in quantities of 1000s to 10,000s annually
  - Structures include other functionality, such that replication provides more than just structural behavior (propulsion, power, thermal,…)
  - May include standards that are evolvable, and potentially include sharing of power, fuel, communications; involves cross-discipline personnel

- Scalable, lightweight precision structures
  - Scalable, in that concepts work for small cubesat scale lightweight structures also works for larger elements, potentially requiring structurally integrated mechanisms for deployment and control; includes scaling law tools for design and analysis
  - Variability in properties is low enough as to not compromise precision behavior (e.g CTE variation across large structure like a sunshade)
  - JWST sunshield has taught up much about complex, lightweight deployables, but we have a lot to learn
  - Includes such things as small optical benches that provide foundation for highly integrated sensor packages

- Real, useful, published performance data on structures in use in their environment (Composite Allowables, Probabilistic Design)

Technology Gaps in Structures Area

- Modular structures is mentioned but does not seem to take it toward the more compelling direction – real production in the near term, highly-integrated structural systems in the long term
  - Modularity and standards in their own right do not enable lower cost if unit count still requires
  - Requires new architecture thinking, cross-cutting with other areas
  - Enables on-orbit operations, robotic exploration, reliability through redundancy and interoperability
  - Networked “resources” which publish health, performance, predicted life, etc.
  - Provides the true commodity bus
- Materials and deployment for larger optical lenses as a replacement for solid mirror approaches
  - Includes materials, coatings, deployment mechanisms, control
- New structural connectivity or materials characteristics that make the launch load strength drivers obsolete
  - Frictional interconnectivity?

Game Changing Technology

- Virtual Design Tool would change design, operation, and safety/reliability of structures and mechanisms
  - The focus here seems to be directly related to the modeling of
- Mass-producible, interoperability highly-integrated structural systems
  - Already mentioned
  - Provides the opportunity to create an evolvable platform for technology development and insertion at <<< $
- In-situ manufacturing (in-space, on surface of other orbiting bodies)
  - A key critical component is control/mitigation of particulate and other manufacturing by-products; not really done well on ground to date
- Scalable, lightweight precision structures with integrated data/health

Tipping Point Technology

- Solar sails – successful flights have already occurred, data uncovered in larger size and flights
  - Larger scale flights, as long as they are properly instrumenta would provide foundation
- Modular integrated for production
  - Multiple venues for trying this out on ground first leveraging the interoperatability laws
  - F6 program is working on some elements of this, but the phyisal manifestation is falling short (an opportunity to leverage other investments)
- Lightweight, impermeable tanks
  - Linerless, nanocomposite tanks have been fabricated and ground tested
  - Pressing for demonstration and inclusion into operational system

Technology Readiness Timeline

- Insertion timeline is variable, depending on the technology being discussed; shorter being better
- That being said, a real push to leverage and even design experiments for small test platforms (e.g cubesats) can provide significant impact on the insertion timeline
  - New Cubesats, and other up and coming new architectures,
  - Readily available and launch via Orbital Sounding Rocket or Cubesat Specific Launcher (in work by multiple parties) provides opportunity for on-orbit data sorely needed
  - Instrumentation, contact and non-contact required to gain data in real operations
- Shorter timelines are enabled by focused development and including inexpensive, available launch as an inherent part of the process (rather than the end)

Questions?