SMALL IS BEAUTIFUL – TECHNOLOGY TRENDS IN THE SATELLITE INDUSTRY AND THEIR IMPLICATIONS FOR PLANETARY SCIENCE MISSIONS, Anthony Freeman, Fellow IEEE, Manager, Innovation Foundry, Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA, USA, Email: Anthony.freeman@jpl.nasa.gov, Tel: (818) 354 1887.

Abstract: It's an exciting time in the space business – new technologies being developed under the 'NewSpace' umbrella have some profound implications for planetary science missions over the next three decades. For example, its easy to anticipate that by 2050 small spacecraft with mass 50-200 kg will be able to do what today's 500-1000 kg spacecraft can do. It will also soon be common practice to incorporate cubesat/nanosat ride-alongs on flagship missions to enable science measurements at close range and in environments that would be considered too risky for the primary spacecraft. NASA's EM-1 and ESA's AIM missions will lead the way on this before the end of this decade. Science results from the ride-along nanosats may have a higher profile than results from the primary mission, and attract much greater public attention – as Philae did on Rosetta. Recent trends also suggest launch costs/kg will be at an all-time low and capabilities at an all-time high.

Telecom, always a problem for deep space missions to the outer planets, will benefit from downlink rates using optical comm that will match today's rates for inner planet missions using RF. Information bandwidth will have increased dramatically as onboard science data reduction becomes commonplace. Space-qualified data processing capability on deep space missions (currently strangled by the 1990's era Rad750) will be just a few years behind the ground-based processing capability of 2050, which will be blindingly fast. As a result, software functionality (AI, autonomy, fault protection, data processing and analytics) on board spacecraft will have grown exponentially from the present date.

In addition, hardware upgrades for long-lived spacecraft in Earth orbit using Additive Manufacturing technology or Satellite Servicing will be as common as uploading S/W upgrades is today. We should expect that additive manufacturing will be used successfully in a low-gravity environment to construct large-scale structures, e.g. a habitat, or a space telescope or a very large antenna.

Spacecraft structures will be multifunction without exception – providing structural integrity, thermal conduction, comm lines, power distribution, and even RF/optical reflecting surfaces. All spacecraft subsystems and instrument components will be 3-D printed. Integration and test will be almost 100% automated. The formulation/design phase will take the 2-3 years it does now – but fabrication, integration and test will be done in a time-span of just a few weeks.

Solar cells efficiencies will have reached a plateau, and batteries will be available that operate efficiently in all expected temperature regimes for deep space missions, from Venus out to beyond Pluto. We will have demonstrated an electromagnetic tether power generation system on at least one outer planets mission. Advances in power and propulsion technologies based on nuclear processes beyond present-day capabilities will depend on whether the US decides that nuclear power is the preferred solution to clean energy (which will trigger significant DoE investment.)

Attitude determination and control systems will continue their advance towards micro arcsec pointing control and cm level precision in formation flying, to the point where such requirements are no longer considered a risk item. Science remote sensing instruments will continue to shrink in power requirements and physical size, with the exception of measurements requiring large apertures. In those cases the mass of the structure forming the aperture will continue to decrease.

Taken together, these projected developments mean that, despite the 'tyranny of the rocket equation', planetary science missions in 2050 will go further and faster than they do today, touch more objects in our solar system, return far more information, and be implemented for budgets and schedules we can only dream of today.

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