"Laptops in Space"
John D. Evans

Good Afternoon. Welcome to Anaheim.

As we take our first steps into the 21st century, our ability to understand ourselves, communicate with our neighbors and even defend our very livelihoods has become dependent upon the satellites we have placed on high.

Surprisingly though, while we can reconfigure the technology in our homes and businesses daily, quickly upgrading to the latest and the greatest, the ability to reconfigure the satellites which circle our earth is next to impossible.

In fact, we conduct our business in space - some of the most critical business of the country - not with up-to-date technology, but with technology that was generations out-of-date the day it was launched and tailored to fit the needs of yesteryear, not the needs of today.

How did this happen?
 Why do we have antiquated systems circling the earth above us, while in our homes we have the fastest, most up-to-date technologies?
 In part, it's because today's satellites are a product of an out dated way of thinking.

To use a computer analogy, current space technology requires we roll back our clock to the 1960s, and fly what are effectively computer mainframes into space.

[Video I: Laptops vs. Mainframes in space

Today satellites are large, complex, highly optimized systems.
Since we do not launch new satellites everyday, we're forced to think long term, designing them to meet our needs for ten to twenty year periods.
We then build and launch these satellites into space and maintain them for years with little or no ability to upgrade them, meanwhile technology back on earth continues to evolve along with the needs of our country.

Think of how these "space mainframes" are fundamentally different from technologies in our homes, such as the common laptop computer.
With laptops, we conduct our every day business with technology that is often only months old.
Advancements happen, seemingly overnight, and we have the ability to upgrade or add components instantly; hooking up a new monitor, printer, scanner, or even swapping out a CPU.
If our laptop isn't where the action is, we take it with us, and deploy the printer at home, the camera at work, or the CPU at the corner Coffee house.

Laptop systems of today are in effect constellations of subsystems that are portable, upgradeable, and instantly re-configurable, allowing them to adapt as technology and our needs change.
To be successful, we need to embrace the portability and adaptability of the personal computer model, creating, in essence "laptops in space".

In the future, satellites will no longer be monolithic constructions designed and launched at a single point in time and for a single mission.
Like latops, they will be constellations of co-flying subsystems, each optimized for its purpose and replaced as it fails, becomes obsolete, or as the needs of the country change.

For example, instead of a single satellite for relaying TV signals back to earth, a constellation system might require a solar power satellite, a main antennae satellite, a data router satellite, and a command-and-control satellite - each located on a separate, small spacecraft, and each with its own navigation and propulsion systems.

The solar power satellite and main antenna may never need to be replaced, but the system may require a new data router package every three years, or a new control satellite every five.
If a critical component fails in one constellation, the system could borrow a satellite from another in real time, until technicians on earth can build and deploy replacement components.
This way we'll ensure the entire satellite system is technically up-to-date and relevant to current needs.

The metaphor "Laptops in Space" represents a new architecture, a new way of thinking, and a new evolution towards building systems in space.
The age of the space mainframe is coming to an end. And it is giving rise to a new age of systems that are re-configurable, upgradeable, and responsive to our changing needs.

[Speech II:

Alan Kay, the man who conceived the laptop computer, once said, "The best way to predict the future is to invent it."

Changing the fundamentals of space technology and the way we operate in space IS the future.

Others at DARPA are currently developing the means to rapidly launch small payloads to space.
But launch is only part of the story.

My colleagues and I in the Microsystem Technology Office are working to make rapidly re-configurable space systems a reality by developing component technologies for satellites, components that are smaller, more sensitive, more reconfigurable, and more affordable.
These are exactly technologies needed to realize this vision of adaptable upgradeable space systems, or more simply "Laptops in Space".

Video II: Current efforts

In recent years, DARPA has taken the lead in developing the new technologies needed to create small satellites, pushing the state-of-the-art in component development: from propulsion and navigation, to communications and electronics.

In the area of propulsion, DARPA is developing propulsion systems for satellites that are so small you could slip them into your pocket, yet powerful enough to reach any point in earth's orbit.
The Micro-Electric Propulsion program is currently developing highly efficient electric micro-thrusters that allow satellites to move to any point in earth orbit using only a few hundred grams of propellant.
Similarly, efforts in Chemical Micro Thrusters are producing arrays of tens of thousands of little MEMS rockets - each like miniature versions of the Space Shuttle booster rockets - that provide the power for quick maneuvers in tight constellations.

In navigation, the Harsh Environment Robust Microsystem Technology program - or HERMiT -seeks to develop packaging technologies that will improve the reliability of accelerometers, such as those used to set off airbags in cars, allowing them to be used for inertial navigation in space.

In the area of radio communications, DARPA's Nano-Mechanical Array Signal Processor Program (NMASP) seeks to develop an ultra-low-power radio system that, instead of using electronics, processes signals using hundreds of vibrating silicon disks and beams.

In the area of electronics, DARPA's Rad-Hard by Design program seeks to make it easier and faster to design electronics that can survive radiation in space, enabling us to use the latest electronics on the satellitesrather than electronics that are generations out of date..

But we are not only working at the component level. In the past three years alone, DARPA has flown three missions with picosats - the smallest of small satellites. The most recent was launched from the Space Shuttle Endeavour in December 2002.

We are, today, taking the first steps on the road to achieving small satellites that function autonomously in space.
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[Speech III: Link to future program concepts

Realizing the vision of reconfigurable, upgradable space systems poses exciting new challenges.
Components aren't enough, we must envision new capabilities, new operational concepts - thinking beyond our current limitations - and envisioning the world not as it is, but as it could be.

DARPA can not tackle these challenges alone.
Though the problem may be DARPA Hard, it is only by working together, that will find the solution.
At DARPA we have struck the doors wide; we welcome the inherent creativity of the entrepreneur - we seek the diversity of ideas that is our nation's strength.
It is time once again for our best and brightest to step forward, and deliver us new capability, a new and unique legacy in space.

What will the future in space look like?
We can no more tell that now, than we could 50 years ago.

But we have caught a glimpse...

Video III: Future Ideas

In the coming years, working with you, DARPA will continue to advance the technologies needed to realize constellations of upgradable, rapidly reconfigurable small satellites in space.
To do this we must not only continue to miniaturize the electronics, communications, navigation, and propulsion systems, but also develop new ways to articulate these small spacecraft, and build them into complex systems

Satellites are not static objects hurling through space, rather they are complex articulated robots.

Solar cells, antenna, and other components must be constantly folded, unfolded, and rotated to keep them safe, functioning, and pointed in the right direction.
In the coming year, DARPA will evaluate whether we can create a new class of small, high-power actuators that bridge-the-gap between conventional macroscopic servos, and comb drives used in MEMS technology.

Electrostatic actuators will employ complex stacks of three-dimensional electrodes.[RIS1]
Microscopic magnetic actuators, will be built with real three-dimensional coils and magnetic cores.
And in micro-hydraulics, we will finally realize the missing link - the microscopic bellows - the key component needed to make complex functional micro fluidic systems.

But creating individual actuators is just the beginning.
DARPA has begun to visualize picosats that can build complex three-dimensions structures in space. These new satellites will be able to take millions of little I-Beams, each no larger than a grain of sand, and like a building a skyscraper, rapidly assemble them into rigid light-weight structures
In the future, small satellites will not be mere curiosities, but fully capable agents providing functionality and flexibility undreamed of in current space systems - a centerpiece of our country's capability in space.

[Speech IV: Conclusion

Over the past decades, DARPA has driven advancements in size, sensitivity, reconfigurability, and affordability for computer, sensor, and space systems.

And the advances continue.

The combination of technologies like those mentioned here, along with those developed from other offices, will enable a change in the way we think about space - enabling us to move from monolithic static space systems, to rapidly re-configurable and responsive constellations of micro satellites - and bringing the revolutionary qualities we enjoy in personal computers to our systems in space, bridging the gap between technology of our homes and that of the heavens.