

## Some Strategic Thinking For Space Settlement

(Personal opinions, not official opinions. Typed and submitted the same day, P.M.)

The President's space exploration initiative rightly stresses sustainability as a key goal in space. But true sustainability is when costs are no greater than revenue. We are far from reaching that point yet in deep space – but even so, a rational strategy would try to get us there as soon as possible, at highest possible probability. It would work back from that goal, in a flexible way, in order to prioritize and plan nearer-term activities.

Total revenues – exports from space to earth – are a key term in this equation. We need revenues “to space” which are massive enough, and diverse enough in their input requirements, to set in motion what economists sometimes call a “takeoff effect,” of self-sustaining economic growth. (The profitable activities that we have today in space are similar to what we used to call a “banana republic.”) Perhaps the most serious possibilities for massive revenue are “space solar power” (SSP), space tourism and space manufacturing. Based on what we learned from the NASA-NSF-EPRI initiative on SSP, and from recent developments in energy economics, I would now view SSP as our best hope, based on all present information; however, a rational pro-space strategy would try to accommodate all three.

The “big picture” of energy and SSP is discussed at [www.ieeeusa.org/policy/energy\\_strategy.ppt](http://www.ieeeusa.org/policy/energy_strategy.ppt). That is a one-hour talk, where every single slide is an oversimplified summary of years of technology research. Here are a few highlights:

1. World dependence on OPEC oil is growing at a very dangerous rate. Rising gasoline prices and issues of war-and-peace and nuclear proliferation, taken together, really do threaten human survival – but we also have technology options that could reverse these trends soon enough (20-40 years) if we get our eyes out of the box and start doing something.
2. Twenty years ago, it was just an oil problem. But if we open the door to more use of primary natural gas, alcohols and electricity – we don't solve the problem. We only move it around. We are importing growing amount of natural gas to make electricity now, and conventional natural gas is just as scarce as oil, worldwide. (Deep gas hydrates may be as plentiful as coal, but extracting them is expensive and riskier than SSP as a technology.)
3. There are three “team A” technologies that definitely could supply all the electricity the world needs, for a long time to come, without destroying the environment: (1) “Texaco/GE IGCC” clean coal with gasification; (2) solar farms using lenses or mirrors to concentrate heat onto a new generation of Stirling engines; (3) SSP. All three have cost risks. SSP has the best chance for being a truly renewable source able to compete on cost with coal and nuclear. We need all three urgently, along with new types of cars on the road.

4. A rational strategy to get the most out of SSP must be grounded in “decision theory” thinking, which admits uncertainty and works to reduce it (while working to develop new options).
5. Crudely – when we issued NSF 02-098 (see [ww.nsf.gov](http://www.nsf.gov)), NASA had recently gotten the bugs out of some very realistic SSP designs, with realistic costing. But the numbers looked like 17 cents per kwh, even assuming earth-to-orbit costs of only \$200/pound. That beats earth solar (because 24-hour electric power is WORTH more per kwh compared to “power when the sun shines”), but not coal or nuclear.
6. For simplified presentations, I say – after NSF 02-098, we now have four very promising design concepts for SSP all of which have a real chance of beating coal and nuclear on cost. The four are (1) John Mankins’ latest ideas for how to do solar cells to microwave beamed power more efficiently; (2) ideas originally from Richard Fork and myself on how to build a laser which converts concentrated light in space to coherent light beamed down to earth; (3) a hybrid solar/fusion concept, using lasers and deuterium-deuterium pellets, which I proposed in my energy papers in the CD-ROM of the State of the Future ([www.stateofthefuture.org](http://www.stateofthefuture.org)), 2003 and 2004; (4) bootstrapping concepts using nonterrestrial materials (NTM).
7. The hybrid concept right now shows the most definite promise of very deep cost reductions. It requires work in several key enabling technologies – most notably, cheaper access to space, proof of the new laser concepts (NOT the same as the Fork type of laser), use of robots to reduce assembly costs, and more efficient power-receiving antennas (rectennas). All four seem doable, but we need to start doing the work to be sure. If we wait too long, we might well lose the option forever, particularly for access to space.

Here at NSS, you know that one of these four concepts – use of NTM for SSP – is far from new. Yet it is still the most futuristic. The classic ideas of O’Neill and of Criswell are exciting and important starting points, but we have a lot of work to do to translate them into realistic engineering options truly ready for affordable deployment.

After many years of experience with major well-conceived government technology development programs, like the National Aerospace Plane (where L5 had a very pivotal role behind the scenes) and the Partnership for a Next Generation Vehicle – we have learned some very hard and very important lessons. One lesson is that selling an idea and getting billions of dollars can actually hurt a technology more than it helps, if the work is put in the hands of lawyer/liar positive thinking political advocates who are less than perfectly honest in describing the problems and uncertainties. Even out of a billion dollar budget, it’s hard to find a few million dollars to address critical bottlenecks and uncertainties if the managers don’t admit that those uncertainties exist. Thus I would advocate a really energetic flat-out effort to try to make the visions of O’Neill or Criswell (or some hybrid) really viable – BUT without any of the wishful thinking or

unconditional claims that some would make. The planning needs to be informed by our best hopes – and by our most sober concerns about what could go wrong.

No matter which variety of SSP we hope for, or even if we hope for space tourism as a source of revenue, the biggest single barrier to day is still the cost of getting to earth orbit. In this area – when I look closely at the technical realities down on the ground floor, I am frankly very, very worried. No matter how good the private sector machine that tries to get us into space, it can't work miracles. There are very tough technical barriers that require the very best enabling technologies, to drive the costs down low enough. Sheer scaling laws say we need a big vehicle to get the best dollars per pound – and we can't afford anything less than the best. Probably, we need to aim at about 1.5 million pounds for the vehicle, the most we can handle easily with airplane-style operations.

NASA has known for a very long time that operations costs are the dominant cost in getting to space, and that aircraft-style operation will be necessary. (For example, see the 1960's reports from Mueller at Goddard, which inspired the idea of a space shuttle – a great idea, ruined by political confusions which are perhaps even more challenging today.) This then requires horizontal-takeoff reusable rockets, at least until more exotic alternatives become available. In fact, at NSF I funded some very aggressive research on some advanced alternatives, through Ray Chase of ANSER and Miles of Princeton University. A startling outcome was that really advanced alternatives can become real only if we first resurrect and enhance some endangered legacy technologies. Realistically, that means that we really need to develop a major program to insert those technologies into a new program for a reusable 1.5-million-pound horizontal-takeoff rocketplane. The most crucial endangered technologies are “hot structure” technologies which would allow such a big rocketplane to return safely to the earth without using the weird and problematic tiles or ablative structures or slush hydrogen that other approaches would rely on. (Hydrogen is fine here, but it helps to have double protection and design freedoms.) Ray Chase has developed a detailed plan for how to do this, using off-the-shelf technology all the way, with a project planning chart that goes out just 4 years.

*If we don't get this done, soon, we will lose the option.* If we lose the option, the whole idea of human settlement of space could become unworkable. This may sound a bit strong, but consider. The critical “hot structure” technology I am talking about was largely black technology, only recently declassified, developed as a byproduct of inadequate satellite observation capabilities and intense universal fear and patriotism in the midst of the Cold War. Reinventing it would be extremely expensive. Even with oodles of money, we do not have the same kind of motivated workforce now. The technology is off-the-shelf... but a lot of the shelves are getting old and creaky, like the key people themselves, and a few key test articles have already disappeared. It would be great if a consortium led by Paul Allen could cough up the necessary \$10-15 billion total cost, and make the necessary deals with the Air Force to contract with Boeing and Lockheed and to supply AF needs... but I hope that this is not our only hope here.

Beyond all this – the assembly of large structures in space will inevitably require a lot of people, even if we achieve the ambitious target of using (human-controlled) robots for 80 percent of the work in hard vacuum. A key role for the moon and asteroids may be to supply sheer materials to those people, to lower the cost of supporting them, exactly as O'Neill proposed. Clearly we need to work as systematically as possible to

make that work, if at all possible. And we need to insert more real brain-like intelligence into these robots, in order to reach the 80-90 percent goal; this is an area where NASA-NSF-DARPA collaboration could be really essential, and where I may claim to know a thing or two. (For example, see my article "Neurocontrollers" in the Encyclopedia of Electrical and Electronic Engineering, J. Webster ed., Wiley, or see [www.eas.asu.edu/~nsfadp](http://www.eas.asu.edu/~nsfadp).)

What about beyond Mars? For now, we really need to avoid losing our chance to get off of earth at all, affordably. But if society were truly rational, there would also be more room for some of the things we would need for a longer-time-frame. In my view, these involve exploring creative but realistic new options in basic physics. I have discussed some of my own ideas for new "out of the box" possibilities in various papers posted at arXiv.org. Now if only there were some way to get some real follow-through...