Server Sky - Space Energy Transformed

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***Abstract*—Information is the most lucrative form of energy. Gigawatts of space solar power transformed into computation and internet service is worth thousands of times the raw energy price, and can be delivered to developing world customers worldwide. Mass-produced, paper-thin, 20 cm wide, 5 gram "thinsats" will connect 4 watts of photovoltaic power directly to processors, memory, and 60/70 GHz radios. Ellipsoid-shaped phased arrays of 7842 thinsats mass 39 kg, maneuver to micrometer accuracy with controlled light pressure, and send gigabit-per-second data streams to sub-kilometer ground footprints. Millions of arrays can populate a 6411 kilometer altitude, 5 pass per day medium earth equatorial orbit and connect billions of people to the global internet. Highly redundant, radiation-resistant thinsats can survive debris fragment perforation and van Allen belt particles, help track space debris, and can be recycled at end-of-life.**

***Index Terms*—Space Technology; Integrated Circuits; Solar Energy; Internet; Globalization**

I. INTRODUCTION

Delivering solar power from orbit to earth remains an unfulfilled dream after half a century. Brilliant innovators have devoted careers to seeking funding, markets, and launch capability, while evolving increasingly sophisticated designs. Their persistence is admirable, but rapid and highly profitable success requires updated goals and strategies.

When Peter Glaser [1] proposed space solar power satellites (SSPS) in the late 1960s, there were a few primitive communication satellites, Saturn V rockets thundered towards the moon, and protesters blocked the gates of nuclear power plants. The time was ripe for space energy innovation, and the tools seemed available for doing so.

Times have changed. Rockets are smaller. Hundreds of communication and observation satellites fill geosynchronous orbit, and hundreds of millions of satellite dishes point at them. Satellite customer costs plummeted, operator profits soared.

Transistors have grown vastly smaller, cheaper, and faster, while becoming far more reliable and radiation resistant. A modern smart phone contains more transistors than existed worldwide in 1970. In 2014, there are more than a quintillion (1E18) transistors. The count doubles every 16 months, 200 times more transistors per decade. World computation capability doubles every year.

The terrestrial internet is power hungry. Data centers consume more than 10 GW in the United States, almost 3% of US electrical power [2], a fraction doubling every 5 years. Most of this power is spent on cooling and voltage transformation; less than 40% of the power reaches the computing load [3].

The global power demand for computing and data distribution may someday exceed a terawatt. Important computations, such as global climate modeling and biological simulation, are limited by the cost of power. Power consumption is the most expensive obstacle to the continued exponential expansion of computation into new applications, limits the deployment of new information technologies, and restricts the growth of the semiconductor industry.

Server sky [4] [5] proposes migrating gigawatts of data center computation into space, bypassing the most expensive problems with space power generation, and solving the most expensive problem for computation growth. By transmitting bits instead of watts, space power can start small and grow to terawatt scale.

II. SPACE POWER TRANSFORMED

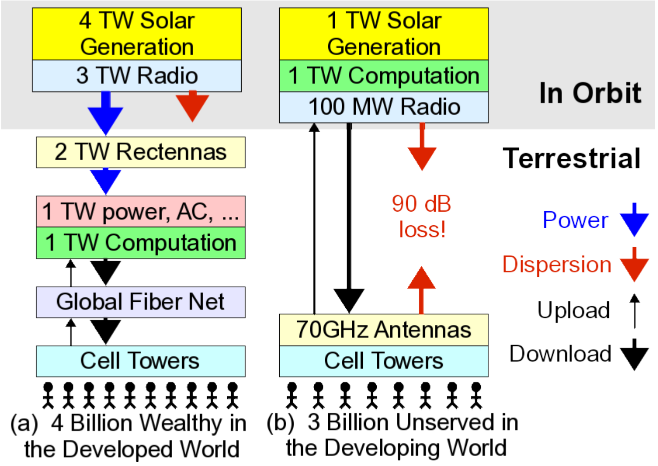

Fig. 1. (a) Hundreds of SSPS satellites broadcasting to the power grid feeding terrestrial data centers, fiber optic networks, and customer cell towers. (b) Millions of server sky constellation data centers broadcasting directly to customer cell towers. Quantities start smaller and increase over time. Both paths replace 2 Terawatts of terrestrial power generation.

Fig. 1 shows two different ways space power can be used to power the internet. The first column represents hundreds of gigawatt SSPS satellites and terrestrial rectennas feeding a regional electrical grid, the second column uses the power in space in millions of arrays of thin film satellites.

An SSPS solar cell array drives gigawatt power lines feeding a giant array of synchronized microwave generators, emitting a microwave beam toward a rectenna on earth, 37 000 km away. Assume 75% efficiency from solar cells to microwaves.

The SSPS microwave beam descends through the atmosphere, perhaps attenuated by clouds or rain, arriving at a large rectenna farm producing grid electricity, transmitted through power lines and voltage converters to data centers. The many losses and conversion steps between space and end user are assumed to be 67% efficient end to end. If the data center is 50% efficient, 1 TW of the original 4 TW actually drives the compute load, the rest is lost along the way.

The second column shows Server Sky, creating and moving information, not watts, to developing world customers in regions without electrical grids and without high bandwidth terrestrial internet service. A terawatt is shown, but individual 39 kg arrays produce 24 kW, and a one ton launch can orbit 25 arrays producing 600 kilowatts. Server sky thinsats directly power backside integrated circuit chips from sunside solar cells, without voltage conversion or losses.

Server sky microwave links are assumed to be very lossy, 90 dB compared to 3 dB for SSPS, but gigabits per second can be extracted from picowatts of received power.

Server sky does not eliminate the need to make terawatts for other purposes - it merely increases the efficiency of a few of those terawatts, producing scalable revenue from a much smaller start. The greatest obstacle to space solar power is inadequate launch capacity. Server sky, growing at Moore's law and internet rates, is one way to finance and rapidly develop that launch capacity.

Server sky does not eliminate the need for the existing fiber connected internet, serving facebook pages and stock quotes to wealthy westerners. Instead, server sky will provide weather reports, market prices, e-banking, education, speech translation, and music to isolated rural people. Afghanistan's Roshan Telecom [6] exemplifies a few of these possibilities. Initial revenues may be small, but multiplied by billions of currently unserved customers can lead, in time, to vast wealth.

Space power and space computing can be a marriage made in heaven. This paper is a brief sketch of a complex idea. For more details and a weblinked and expanded version of this paper, visit http://server-sky.com/WPT .

III. KILOWATTS INTO GIGABITS AND DOLLARS PER SECOND

Moving information is cheap. Ideally, a bit can be captured from absorbed microwave energies of kT ln(2) (3e-21 joules at room temperature), and practically from ten times that.

A 3W (4.8dBW) Middle Earth Orbit (MEO) transmitter, 8400 km (56 ms round trip) away from the receive antenna at 35N, with a array transmit antenna gain of 78.4 dB, a path loss of -207.8 dB, an atmospheric and elevation loss of -20.0 dB, and a receive gain of 39.3 dB produces -105.3 dB, enough to move a gigabit per second.

Assume we can produce 3 W at 70 GHz with 30 W of DC feed power. 1 kW of DC power could produce 33.3 Gbps in multiple arrays. Smart phone data transfer retails for $6/GB [7]. A kilowatt in orbit can be transformed into as $25 of retail data transmission per second, rather than $0.06 of retail electric power (Est. 50% space photovoltaic to customer ($0.12/kWh) wall socket efficiency).

When American farmers settled west of the Allegheny mountains, 600 kg of rye required three pack animals to transport to eastern markets, and sold for $6. The same rye could be distilled into 30 liters of whiskey, transported on one pack animal, and earned profits approaching $16 [8]. Space power has similar transportation difficulties, and similar solutions. Transforming space power into high value products before shipment reduces costs and increases value, especially to new customers in underdeveloped regions.

India has 400 000 cell towers providing basic telephone service, mostly off the electrical grid and connected by microwave links, consuming three billion liters of diesel per year [9]. Broadband internet requires far more data capacity and power consumption. Data backhaul from orbit can save gigawatts of generation and billions of dollars in equipment. Gigabit connections to exascale computing will help billions of people educate themselves and climb out of poverty.

Christensen [10] teaches that startups providing essential needs to previously unserved customers succeed 40% of the time, while a startup attempting to enter a mature market with established competition has only 4% chance of success. Internet service lifting billions out of poverty for kilodollar per-village investment may succeed sooner than billion dollar gambles against conservative power company monopolies in developed world power markets.

We can evolve towards SSPS faster if we begin from a more secure starting point, with established high volume launch, hundreds of square kilometers of space power producing high profits, and the mature technologies evolved from server sky. The billions of rapidly developing people will want grid electricity, and SSPS will be an attractive and familiar option.

IV. SPACE POWER'S SOLID STATE MAKEOVER

Satellites are essentially energy-processing surfaces. Ivan Bekey teaches us to replace structures with information, build gossamer structures in distributed systems, and transport energy and information, not mass [11]. Middle Earth Orbit (>2000 km altitude) is subject to extremes of radiation and temperature, but is free of friction, contamination, and mechanical stress. Satellites have line-of-sight access to vast areas of the earth. Low drag orbits are precisely predictable.

Mesh networks can connect thousands of small satellites in a three-dimensional obstruction-free environment. Thin satellite array function-to-weight ratios can be orders of magnitude better than terrestrial infrastructure or aircraft-style satellites.

220 nm thick direct-bandgap indium phosphide photovoltaic cells collect sunlight with 15% efficiency, 200 W/m^2 [12], weighing 1 g/m^2. More efficient multilayer cells are possible, but are far more expensive and vulnerable to radiation.

Integrated circuit silicon is cheap and lightweight, power is expensive. The lifetime power cost of a typical microprocessor is higher than the production cost [3]. Thinned to 20 μm, a 10 mm^2 die weighs 500 μg. It is cheaper to move silicon to the power source, rather than power to the silicon.

Integrated circuit chips for RFID tags are as small as 50 μm x 50 μm x 5 μm, draw milliwatts of power, weigh 30 ng, cost

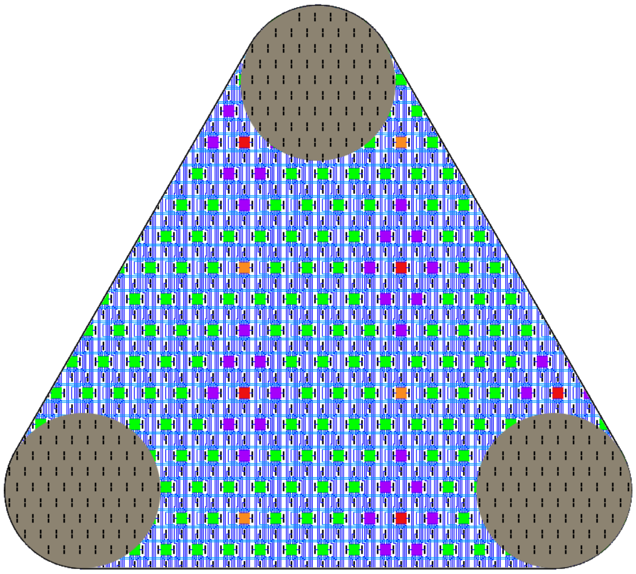

Fig. 2. Thinsat back side chip array, 20 cm wide, 70 μm thick, 5 g, not to scale, real thinsats will have 1400 2.1 mm slots and 350 chips. The black vertical bars represent slot antennas, the corners are electrochromic light pressure thrusters. Antenna slots pass through the aluminum foil substrate to the front, covered with InP photovoltaic cells and corner thrusters

a fraction of a cent, yet contain thousands of 90 nm transistors [13] [14]. Cost and size plummets exponentially with time.

V. SERVER SKY

The primary task of server sky arrays will be data center computation; retrieving and formatting data from solid state memory, data analysis, simulation and modelling, sound synthesis and analysis.

Server sky arrays will source data, rather than retransmitting ground station data in real time like the O3B [15] satellite network. Ground communication will use a small fraction of the power used for computing. Server sky arrays are not communication satellites, no more than a terrestrial internet data center is a telephone repeater. Server sky communication is point to point, using 4.3 mm, 70 GHz beams from a large array in 12789 km orbit to paint sub-kilometer ground spots feeding single antennas, typically attached to cell towers.

Cross-orbit and intra-array communications in vacuum happens at 60GHz. That frequency is strongly absorbed by atmospheric oxygen resonance and does not reach the ground.

Server Sky will convert space solar power into computation in distributed arrays of small solid-state satellites. Server sky **thinsats** will be rounded triangles 20 cm across, 240 cm^2 in area, and weigh 5 g. Thinsat front sides will be covered with indium phosphide solar cells.

Thinsat back sides, illustrated in Fig. 2, will be covered with 1400 2.1 mm slot antennas in a hexagonal grid at full-wave spacing, cut through a 70 μm thick aluminum substrate [16]. Groups of 4 slots are fed by 3.6 mm x 3.6 mm x 20 μm thick customized integrated circuits, all with built-in RF power modulators. The chips are a mix of simple microprocessors, ROM, and RAM, and connected by a redundant mesh of low voltage high speed wiring. Advanced semiconductor processes are complex and expensive; there will be large non-recurring engineering expenses spread over billions of production die.

The larger-than-halfwave spacing will create grating lobes spaced 60 degrees from the main downlink lobe; Fortunately, the earth occupies less than 60 degrees of the sky, so waste downlink power will disperse harmlessly into empty space. The waste power is defocused by thinsat curvature, frequency spread, and the nonuniform array. There will not be enough concentrated power to interfere with other services.

Thinsats will deploy into actively stabilized three dimensional geodesic arrays. Array sizes can vary from hundreds to millions. This paper considers arrays of 7842 thinsats, producing an average of 24 kW for computation and radio.

Server sky orbits will not be geostationary. Thinsats will be launched in 40 kg solid-cylinder stacks into 6411 km altitude equatorial orbits, about twice the radius of the earth. This is in the inner van Allen belt, a high radiation zone with few other active satellites. Compared to GEO, the MEO orbit reduces round trip ping time, path-length attenuation, and the size of the ground footprint for point-to-point communications.

Arrays will pass through the sky five times a day, every 288 minutes, so this orbit is called **M288**. Arrays will eclipse 17% of every orbit in spring and fall, 11% in summer and winter. Arrays will go into cold shutdown when eclipsed, while other visible arrays in full sunlight continue to serve customers. Extra arrays are cheaper than batteries.

Server sky data centers do not need chip packaging, power conversion, air conditioning, land, structure, or fiber data links. Thin film space systems assembled with photolithography and automation may cost less less than traditional earthbound systems, with more versatility and fewer environmental costs.

A 1400 kg to GTO booster such as India's PSLV [17] can put 24 40kg arrays (with spares) into equatorial M288 orbits. Any launch system capable of 10 km/s delta V can dispense dozens to thousands of server sky arrays.

VI. ENVIRONMENTAL EFFECTS

If space computation power grew to a terawatt, 250 billion thinsats facing the sun at M288 could reflect 25% as much light into the night sky as the full moon, disrupting nature and optical astronomy.

So, thinsats will turn edge-on to the terminator in the night-side half of the orbit to eliminate night sky light pollution, reducing average power by 17%.

Thinsats cool rapidly in eclipse, By turning the high thermal emissivity backside coating towards the nearby warm earth, thermal shock is minimized. Interconnect should have high compliance to tolerate large thermal expansion differences.

The arrays shade the earth an average of 13.2% of the M288 orbit. 250 billion thinsats have an area of 6250 km^2, so the average earth shading is 825 km^2, compared to 125 million km^2 of sun-facing earth surface, similar to a 7 part-per-million increase in clouds.

VII. Light Pressure Maneuvering

Thinsats will have area-to-mass (“sail”) ratios of 5 m^2/kg, maneuvering as light sails such as the Japanese Space Agency’s IKAROS [18]. Heavier than true solar sails, thinsats will have enough thrust to travel in formation, avoid colliders, and migrate from underutilized arrays to larger ones.

1360 W/m^2 sunlight makes a tiny 4.54 μPa pressure if absorbed, and double that if reflected. The three corners of a triangular thinsat will be 5 cm diameter (19.6 cm^2) electrochromic mirrors, which electrically switch from dark to reflective, changing acceleration by 3.5 μm/s^2. Thinsats will accelerate relative to array center by $\pm$1.8 μm/s^2. Position can be adjusted to 0.4 μm accuracy, calibrated by radio time of flight to neighboring thinsats.

Thinsats will turn with an angular acceleration of 350 μradians/s^2. A turn and stop to a 45° angle will take 16 minutes. Turn time limits size; increasing thinsat area 16x doubles turn time. Reflections from tilted thinsats will make lateral thrust perpendicular to sunlight.

Accelerations will be small, but accumulate to large displacements over hours and months. If a thinsat accelerates for 30 minutes and then decelerates, it will move 5.7 m relative to the rest of the thinsats. A 1.6 km movement will take 24 hours. A thinsat can move 40 000 km, halfway around the M288 orbit, in half a year.

Thinsats will not be flat, but slightly convex, with different curvatures in orthogonal directions. Curvature adds stiffness, compensating for substrate weakening by the slot antennas.

Torques and bending moments from the thrusters can cause vibrations, with approximately 0.01 Hz frequencies. There is no natural damping, so vibrations may accumulate over time. Larger vibrations can be measured by time of flight to neighboring thinsats, and dampened with thruster toggling.

Thinsats will be stacked into solid cylinders for launch, turned at 0°, 120°, and 240° in groups of 3 through the stack. Because of thinsat anisotropic curvature, stacks will push apart like weak Belleville springs. A thin anti-stick backside coating will help thinsats peel off the stack in zero gee. Alternately, thinsats may be deployed centrifugally from the outside of a spinning cylinder. Deployment must be slow, so that μm/s^2 light pressure acceleration can remove velocity. Dampening vibrations and settling into position may take days.

VIII. Radiation

Radiation will be the number one problem for server sky thinsats. Recent advances in solar cell materials and VLSI radiation hardness, a fortuitous result of transistor scaling, permit unshielded gram-scale satellites.

The Intel hafnium oxide gate stack, designed to reduce gate leakage, produces transistor gates highly resistant to charging by ionizing radiation. Modern digital processes operate at supply voltages too low to sustain latch-up. New microprocessor designs that recover from noise errors [19] can evolve into designs that recover from radiation-induced single event upsets. Thin indium phosphide solar cells can survive radiation doses of 10^{18} electrons/cm^2 (1 MeV) [12].

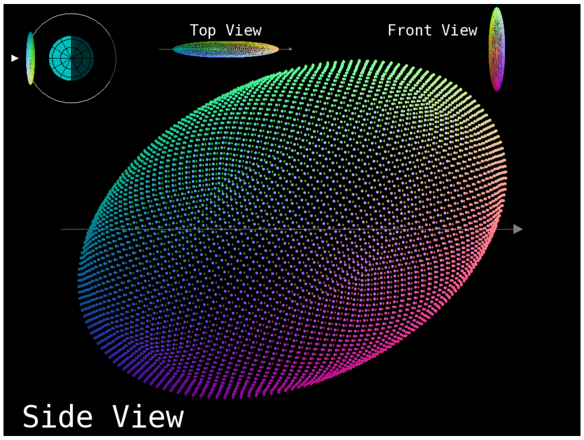

Fig. 3. 7842 Thinsats in a skewed V=28 geodesic array, 100 m wide. Array size exaggerated 10 million times in relation to earth.

IX. Geodesic Arrays, Radio, and Ground Patterns

A grid of 1400 slot antennas, cut through the aluminum substrate of a server sky thinsat, form a phased array antenna. Arrays of thinsats will combine into larger antennas, which can simultaneously send many narrow packet beams to sub-kilometer-sized receiver footprints on the ground. Packet parallelism is computation power limited - as silicon processes improve, so will thinsat bandwidth.

Thinsats will be arranged in a skewed icosahedral geodesic sphere. A V=28 array, shown in Fig. 3, will contain 7842 ($10V^2+2$) thinsats, 100 meters across with 1 m spacings.

Assuming a 70 GHz (4.3 mm) downlink and a 100 m wide array, the ground spot will be 300 m across between the first Airy disk nulls. Two targets a kilometer apart can receive two different Gbps signals from the same direction. This won’t provide superhigh bandwidth to a dense urban environment, but works well for suburban, rural, and mobile customers.

Thinsat arrays will be widely spaced to improve light penetration, focusing intense central lobes but splattering most transmit energy into useless sidelobes. Typical regular-grid flat phased arrays create concentrated grating lobes. Geodesic arrays will splatter the same sidelobe energy more uniformly, adding to background noise but not creating high gain interference. The off-axis energy also spreads by the ratio of channel bandwidth to the carrier, 1/70. For example, a sidelobe 210 km from the central lobe will smear radially from 300 m to 3 km, attenuating power by 10 dB.

Thinsat arrays will be skewed and rotated by orbital mechanics. Relative to the center of the array, the radial distance becomes orbital anomaly (angle) distance one quarter orbit later. Thinsats in the array follow a small elliptical path around the array center, twice as long in the tangential direction as the radial direction. The small eccentricity is combined with a small inclination, so the array appears to rotate around the orbital track, once per orbit and 1.2 times for every M288

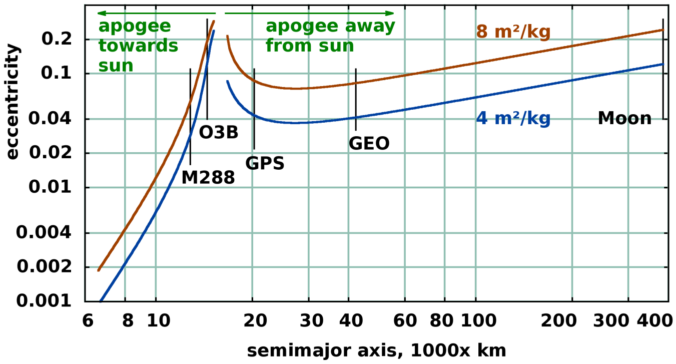

Fig. 4. Eccentricity compensation for light pressure perturbations. Lighter thinsats with more sail area per mass cause more orbit change. At the asymptote in the middle, earth oblateness J_2 precession matches the solar year, and light pressure perturbations accumulate without compensation.

overhead pass, 6 turns per day. Thinsats "orbit" the array centerline at speeds up to 3 cm/s .

An intriguing ground antenna design from Kymeta [20] uses liquid crystals in a metamaterial configuration as a Ka band antenna. Intended for the O3B [15] satellite constellation, these antennas steer slowly (30°/s) and are not suitable for time-sharing many users to many server sky arrays at once. However, they are efficient and inexpensive, and justify the expense of relays arrays between server sky arrays in orbit, concentrating many data streams into one download.

As ground cells fill with receivers, wider antennas can select with better angular precision, and larger orbiting arrays can focus on smaller cells. Inclined orbits nested around M288 add north/south selectivity but require two axis ground antennas.

Signals will be sent as hundreds of parallel megabit-per-second channels, demodulated at low bandwidth and recombined digitally at the receiver. This tolerates wavelength-dependent propagation delays, rain dispersion, and clouds, and permits thinsats to broadcast the same data from all slot antennas simultaneously, though carrier phasing will be adjusted per slot antenna for beam steering.

Uplink from small antennas will be slower than downlink. This matches typical asymmetrical internet usage. With few customers in the mid-Pacific, bulk content can be uploaded from large high-bandwidth ground antennas sited near trans-ocean data cables, far from sensitive observatories on Hawaii.

X. LIGHT PRESSURE, BALLAST, AND SPACE RESOURCES

Light pressure distorts orbits, shifting apogee and perigee eastward (viewed sunwards). The minimum eccentricity of a precessing orbit increases with sail ratio (area over mass) and orbit radius. The elliptical orbit must not precess into the paths of other satellites, limiting the maximum sail ratio. Thinsats in the M288 orbit will have a sail ratio of 5 m^2/kg. Higher orbits require smaller sail ratios, as shown in Fig. 4.

Thinsat light pressure can be reduced with a micron-scale infrared-reflective metal mesh across the front of the thinsat. Tiny glass lenses in the gaps can focus sunlight on small spots of solar cells, making them more radiation resistant. Heat radiates isotropically from infrared-optimized emission surfaces on the back, partially balancing front side light pressure. Sail ratio may be doubled, launch mass halved.

Launch mass can be reduced by attaching ballast mass in orbit. Recycled obsolete thinsats will be one source of ballast, gram-weight pellets cut from captured space debris will be another. When all the space debris is used up, lunar regolith can be formed into pellets and launched to M288, the simplest form of "space manufacturing" imaginable.

Derelict rocket bodies may be processed into foil, and someday lunar-sourced aluminum will be available. Thinsat aluminum foil substrates, solar cells, and wiring can be manufactured in orbit, shipping the integrated circuit chips and high purity materials from Earth. Substrate production requires hundreds of material processing steps using complex deposition and patterning tools, similar in production effort to a flat panel display. The many meter-scale machines will be small, perhaps less than 100 tons for a manufacturing line. Manufacturing scale is another reason for small thinsats.

Chip factories (fabs) are giant buildings full of fragile machinery operated by legions of engineers and scientists. Fabs are far heavier than the chips they produce and belong on earth. Indium, concentrated on earth by oxygen and water and plate tectonics, will not be found on the moon in usable ores. Metamaterial researchers may someday develop direct bandgap photovoltaics from lunar-abundant ores.

XI. DEBRIS COLLISIONS AND DEBRIS TRACKING

Most debris objects are in low earth orbit (LEO). M288 is far above LEO, and the collider density is 1000 times smaller. Small objects may punch holes through a thinsat, degrading but not disabling it. Thinsats will always be under precision control from deployment to obsolescence; even completely disabled thinsats can be sandwiched by two other thinsats and transported for recycling. If a thinsat escapes all constraints and collides with another satellite, a 5 m^2/kg thinsat collision at 4 km/s deposits 800 J/cm^2 (compared to 40 KJ/cm^2 for a 5 g bolt). System design and operation must never permit this.

Internet customer demand will grow exponentially, but in the beginning demand and revenue won't pay for server sky. Thinsats will be adaptive millimeter-wave energy sources, reprogrammable as look-down radar. Accurately predicting a collision, days in advance, threatening billion dollar satellites or the International Space Station provides more time to move, using less thrust. Mapping space debris can pay for server sky before the first internet ground station is deployed.

Widely spaced, picosecond-accurate thinsat arrays can combine coherent kilowatt 60 GHz transmit beams in a region of space a few hundred meters across, producing standing waves. Objects traversing the standing wave region produce narrow-band amplitude and phase patterns that can be correlated and identified by other arrays configured as bistatic receivers. It may be possible to locate small objects with centimeter precision. This will reduce threats to server sky arrays, and make low earth orbit much safer for all other satellites.

As server sky grows towards billions of thinsats, precisely positioned by light pressure rather than reaction mass, the resources available for locating ever-smaller debris objects will soar. Current behavior pollutes orbital space with reaction mass, upper stages, and failed satellites with little thought of the future. The new ethos must be "no gram left behind".

XII. COMPARING SSPS WITH SERVER SKY

Server sky startup advantages relative to SSPS:

- 1 ton rather than 40 000 ton minimum production system
- Kilodollar data, not electricity worth pennies
- new unserved markets, not entrenched monopolies
- no interference with existing microwave communications
- 7x more power per launch mass
- less launch mass with ballast and infrared filtering
- space debris usable as ballast
- uses light pressure rather than maneuvering fuel
- redeployable in orbit, migration between arrays
- reprogrammable for space debris tracking
- can use any size launcher
- ΔV to orbit 9.8 km/s rather than 11.5 km/s
- mass producible like flat panel computer displays
- new arrays will be more productive at Moore's Law rates
- evolutionary path to lunar material manufacturing

The world still needs clean grid power, especially in the developing world, and SSPS will provide that someday. Server sky is a faster evolutionary path to SSPS, not a substitute.

XIII. CONCLUSION

From a few small server sky arrays, we can double capacity annually at Moore's Law rates, and build a spacefaring global civilization in a generation, while relieving the global grid of the internet's huge energy appetites.

Server sky will bring abundant information and connectivity to the earth's poorest people, making them wealthy enough to contribute to technological development. Information and cleverness can substitute for energy use; when we engage the brightest minds on the entire planet, rather than in a few wealthy countries, productivity per kilowatt hour will skyrocket, and the cost of new space technologies will plummet. We will learn how to provide better-than-rich-nation living standards with less-than-poor-nation resource consumption.

We will have abundant resources to develop practical SSPS, and the wealth to purchase it. Server sky will pay for the low cost, high capacity launch systems that deploy SSPS, and create billions of new customers for SSPS power.

The pioneers of space solar power have waited a lifetime to see their hard work pay off. Together we can rapidly deploy server sky, and our heros can see their dreams come true.

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