

“Futures” of Space Technology
“Frontiers of The
Responsibly Imaginable”

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Space Technology Issues/Metrics

- Bandwidth
- Resolution/Aperture
- Propulsion
- Power/Energy Storage
- Space Access
- Radiation Protection
- Size/Weight
- Sensitivity
- Machine Intelligence
- Affordability
- New/Different “Observables”
- ‘Protection’
- Reliability

THE KEY TECHNOLOGIES

(highly synergistic / at the frontiers of the small / in a “feeding frenzy” off each other)

- **IT** (comms/computing/sensors/electronics/machine intelligence)
- **Bio** (genomics/molecular biology/designer life forms)
- **Nano** (coatings/barriers/computers/sensors/materials/“assemblers”)
- **Energetics** (HEDM (various)/revol. solar/biomass/explosives/propellants/storage)
- **Quantum**
[crypto/computing/sensors/optics/Electronics]

Ongoing Space Technology “Revolutions”

- **Micro/Nano Sats**
 - **Far lower launch costs [value/lb vs. \$/lb]**
 - **Far greater launch “flexibility/ubiquity”**
 - **Toward “Everymans” Capability” [\$45K fab and ride - Utah Co.,Tokyo Univ.]**
 - **Co-operative Conops/”Formation Flying” for Aperture [Multitudinous enabling approaches/technologies]**

Ongoing Revolutions [Cont.]

- **Nano Sensors, Orders of Magnitude Improvements in: sensitivity, bandwidth, size [red.], Cost [red.] - i.e. E-6 degree IR sensit.**
- **Energetics:**
 - **Thermal Diodes [20%-30% Direct Conversion]**
 - **Zeolite H₂/Methanol Storage [Ionomers]**
 - **CNT Flywheels, MIT MEMS Rockets**
 - **LENR's, SMES/CNT Magnets**
 - **HEDM [Various]**
 - **Tethers, Room Temp. S-C**

Ongoing Revolutions [Cont.]

- **Materials:**
 - **SWCNT/NNT**
 - **Gossamer Membranes Etc./"Light Buckets"**
 - **In-space e-beam based free form fab**
 - **Syntactic foams, Str. Amorphous metals, micro-structured materials, brilliant materials**
- **Computing /Comms.**
 - **Optical Comms in-the-large**
 - **Bio/optical/Quantum/CNT/Molecular Computing**

Potential CNT Applications

- Overall [structural/radiator] weight reductions order of 3 to 8
- Flywheels
- Mag. Sail
- [Better] Tethers
- Ultra Capacitor
- Sensors/Computing/Electronics - 2-4 orders of magnitude improvements...
- High/Room Temperature S-C
- Extreme multi-functionality

Carbon Nano-Tubes.....

- **A “One-Stop Shopping Brilliant Material”?**
 - **Nascent/Coincident Sensing,Petaflop
LOW ENERGY Computing,EM
Actuation,[H2,E-M] Energy
Storage,Huge strength-to-weight,Anti-
Radar?**

Membrane Structures

- **Lightweight/Deployable/Inflatable/Rigidizable [Including Struts/Trusses]**
- **100M to 1000M Apertures [eventually]**
- **Multitudinous Applications**
[“sails”,antennas,”light buckets”,solar arrays,planet/life finders”,concentrators, mirrors,lenses,radiators,sunshades....]
- **Distributed actuation/power/processing/sensing**

Ongoing Revolutions [Concluded]

- **Misc.**
 - **Nano optics [1/100th size/weight/cost]**
 - **Nanobots**
 - **Machine Intelligence**
 - **Insitu robotic repair/refueling**
 - **“Revolutionary Rocket”**

AI (AND BEYOND) COMPUTING

Human Brain Characteristics/Capabilities

- **100 billion neurons**
- **100 trillion connections**
- **200 calculations/second, (slow) speed of neural circuitry**
- **20 million billion calculations/second**
- **Excellent at (parallel-computing) pattern recognition, “poor” at sequential thinking**
- **Operates via “random tries”**

Machine Capabilities

- **Currently, 200,000 billion calculations/second**
- **By 2012, 20 million billion is available (by 2025, on a PC)**
- **By 2030, PC has collective computing power of a town full of human minds**

Machine Intelligence

- **Approaches:**
 - **Experiential - Behavior Based/'learning'**
(neural nets/other “Soft Computing”)
 - **Nano-section/replicate brain in Silicon**
 - **“Emergence”**
- **Should produce Artificial/Cyber “life”
which will possibly-to-probably be
sentient but will not be anthropomorphic**

“Beyond” NANO - Quantum Synopsis - Quantum Technology

- **Largely enabled by/synergistic with NANO and Femtosecond Lasers**
- **Tailoring/Utilization of (mainly two-state) “Quantum States” - electron or nuclear spin/energy level, Photon polarization/spin, Super conduction charge number/phase (Qubits - Quantum bits)**
- **Especial Technological interest in Revolutionary capabilities derived from Quantum Entanglement (Produces/exhibits non-classical, non-intuitive, NON-LOCAL behavior).**
- **Entanglement defined as highly correlated Quantum states. If entangled material is separated spatially a change in one portion INSTANTANEOUSLY changes the other portion irrespective of distance.**

Quantum Technology Arenas

- **Zero Point Energy**
- **Cryptography keys**
- **Materials (nano at the quantum limit, magnetics)**
- **Sensors (including Quantum well Infrared detectors)**
- **Computing (Progressing very rapidly, petaflops and beyond)**
- **Imaging (“interaction free,” Quantum holography,)**
- **Information Systems**
- **Communications (Instantaneous irrespective of distance, usefulness TBD)**
- **Optical Systems (e.g. Quantum Interferometry)**
- **“Electronics”**

Quantum Effects in the Macro/Classical World

- **Lasers**
- **Bose-Einstein Condensate**
- **Super-Fluidity**
- **Super-Conductivity**
- **Quantum Entanglement**
- **Fermionic Condensate**
- **Quantum Magnetic Deflagration**

ACCESS TO SPACE

THE (USUAL) DESIGN OPTIONS

- **Rockets (various)**
- **Airbreathing (various)**
- **Staging (single, two, three, etc.)**
- **Reusable/expendable**
- **Horizontal/vertical T/O and landing**
- **Fuels (various)**
- **Manned/unmanned**
- **Materials (various)**
- **Controls (various)**

Thus far--no clear “winning combinations” for either affordability or flexibility metrics, are agonizing along evolutionary development paths, worldwide

Revolutionary Rocket Technologies

- Propulsion Cycle:
 - a) PDWR - order[s] of magnitude reduction in turbine feed pump pressure [huge cost /reliability payoff], Deton. In Liquid Fuel
 - b) Base Region Augmentor - “poor man’s Airbreather”, use hypermixing to entrain external air, triples thrust/doubles payload
- Fuels - HEDM [e.g. Cubanes/N₄, atomic C/H...], Isomers, Anti-matter, H-B-11 Fusion
- Materials - SWCNT, NNT, Micro-structured Materials, Amorphous metals, free-form Fabrication

Revolutionary rocket Technologies - Continued

- “Designer Aero’ - “Flow Control”, obviate “Ballast/packaging problems” & obviate shock Drag [forward liquid injection]
- Launch Assist:
 - a) Beamed MW’s from ground to Rectennas on side of bird, Energy powers base region MHD Accelerator, enables 2500 Sec. Of Isp
 - b) Polymer-stabilized/laser guided high Pressure Water Jets
 - c) Tidmans “Slingatron”
 - d) Tethers

An Approach to Orders of Magnitude Reductions in Weight/Cost of Exploration “Upmass” to LEO

- **Collect/Pressurize in-space “Propellant Mass” [not fuel] from “upper Atmosphere”, re-use collected disassociation energy**
- **Utilize an in-orbit “Beamer” [space infrastructure/utility] , transfer collected energy to the vehicle [MW’s/Rectennas,Lasers/PV]**
- **High Thrust/High g acceleration in near[er] field of the beamer out of the Gravity well using MHD accelerator with Isp ~ 2000 seconds**

Possible MHD Synergisms

- **MHD Accelerator:**
 - In-space Propul. via Beamers
 - “Launch Assist” via Ground-based Beamers
- **MHD Generator:**
 - Regenerative Aerobraking

[Sampling of] HEDM Candidates

- **SBER**
- **Metallic H₂**
- **Solid H₂ with Atomic C/B/H**
- **Cubanes/N₄**
- **Metastable He**
- **Positrons/Anti-matter**
- **Quantum Nucleonics [Isomers]**
- **H/B-11 Fusion**

Aneutronic H-B 11 Fusion

Inertial Electrostatic Confinement Fusion [QED,IEC,IEF]

- **Produces Protons,Direct MHD Electricity Generation vice [Neutron] Thermalization**
- **Reduced Radiation Hazard[s]/Weight**
- **High Thrust-to-weight AND High Isp [via reduced - shielding,magnetics,High Power Drivers]**
- **For SSTO,Payload Mass Fraction is ~ 14%,Launch Cost Estimate ~ \$100/lb**

Nominal Power Densities

- **ZPE.....E108 X Chemical**
- **Anti-Matter/Positrons.... E10 X Chemical**
- **Fission/Fusion..... E6 X Chemical**
- **Isomers..... E5 X Chemical**
- **SBER..... E2 X Chemical**
- **Hydrogen.....38 KWH/Kg**
- **HC.....14 “**
- **Advanced Flywheels..... .9 - 20? “**
- **Batteries..... .04 - 10? “**
- **SMES..... .0015 - ~100? “**
- **Super/ultra Capacitors..... .0007 -8? “**

Energetics “Wild Cards” Being Worked

- Solitons for Divergence Free Power Beaming
- Positron Storage as Positronium
- High Efficiency Plastic Nano PV
- 30%+ Thermo-Electrics
- High Efficiency [KW/KG] Fuel Cells
- “On-Site” H₂ Generation vice Storage [Zinc,....]
- Room Temperature S-C
- Tapping ZPE
- Controlled Nuclear Isomer Release
- SMES with CNT Magnets
- Lithium Tantalate Crystals

Soliton Energy Transfer.....

- Solitons are waves in non-linear systems which are non-dispersive, "maintain amplitude"
- Utilized in optical communications [information transfer], up to 1,000,000 Km thus far
- Physics evidently allows utilization for Energy Transfer, Not yet accomplished
 - Would change Energetics MUCH [DE weaponry, SPSats, Beamed Energy Propulsion,.....]

“Sensors are poised on the
Brink of a Revolution Similar
to that experienced in Micro-
Computers in the 1980’s”

Jon Wilson, 2004

Editor-in-Chief, Sensor Technology
Handbook

Sensor Trends

- **Mini-to-Micro-to-Nano**
- **Hyper-Spectral**
- **Multi-physics**
- **Hyper-Sensitive**
- **Hyper-Resolution**
- **Integrated with Actuators, Processors, Comms**
- **Sensor Webs/Swarms/"Networks"**
- **Lower Power, Energy "Harvesting"**
- **Brilliant**
- **Ubiquitous**
- **Data Fusion/Sense-Making**
- **"Wireless"**
- **Apertures from Co-op conops, Membranes**
- **Active and passive**

[Sample] Emerging Sensor Technology areas

- **Terahertz**
- **Biomimetics, Bio [living] sensors**
- **Protein Engineering**
- **Femto-second Lasers**
- **CNT's [bio,chem]**
- **GPS as active sensor "Source"**
- **Infrasound**
- **Atmospheric static E Field**
- **Cadmium-Zinc-Telluride Gamma Ray Sensors**

The Sensor Capability Spiral

- **MEMS Technology enables ever smaller Sensors/Instruments which**
- **Reduces requisite energy/power and**
- **Improves sensor response and**
- **Increases sensitivity and also**
- **Reduces cost[s] thereby enabling**
- **Huge increases in sensor ubiquity/Networks [10,000....] and Resolution**

And Then There is NANO.....

Sample Nano-Sensor Frontier

- **Nano/RFID tags [w/138 digits ID every molecule on Planet, Japanese Children , Mexican Police & Hospitals/Walmart/ETC....]**
- **Smart dust[comms/sensors/PV - mm]**
- **Quantum entanglement-based sensor enhancements**
- **10^{-6} F IR focal plane arrays (nanocantilevers)**
- **Single molecule detection, detection of single molecules**
- **F-sec laser induced signatures**
- **Atom optics/Matter wave sensors [E4-to-E6 improvements, esp. gyro/inertia Sensors]**
- **Nav via pulsing cosmic X-ray sources**

Sample Characteristics of Emerging Global Sensor Grid

- **Military, Commercial/Industrial, Public Safety, Scientific, Populace Contributions/Observations**
- **Ever-Improving Sensitivity, Resolution, Ubiquity, Connectivity, Fusion/"Sense-Making", Physical Phenomena "Coverage"**
- **Land, Sea, Air, Space, "Internal"/External**
.....

Capabilities Enabled by the On-Going Tech. Revolutions

- **GEO+ “Long Dwell” systems, <1m**
- **Miniaturized, affordable, ultrasensitive, ubiquitous, lightweight, Brilliant, low power Req., ultraspectral, multiphysics, long-lived Multi-purpose/Reconfig. in-space “assets”**
- **Rapid/inexpensive reconstitution**
- **Huge Apertures [sparse arrays, membranes]**
- **Requisite Band widths**



Launch Tube
Vacuum

Pump

Drive Motors
Foundation

~300 m

12-turn Spiral,
Gyrating on a 3.0 m radius at 9 Hz

Femto/ATTO-Second Lasers

- **Order E-15 Pulse Length, a “scalpel”**
- **Improved Atmospheric Propagation (< breakdown time), “Pre-Plasma Channeling”/en-route amplification**
- **Can “cut through anything,” 100 Terrawatt to Petawatts per pulse**
- **Wholly new/different material Interactions/Kill Mechanisms, no “protective plasma layer” formation, Huge localized electrical/magnetic fields (>atomic forces)**
- **Can be small/inexpensive**

Femto/ATTO-Second Lasers

Applications

- **Sensing**
- **Laser and (from “secondaries”) - gamma/x-ray (effective defense against hordes/swarms)**
- **Fission ignition (accomplished)**
- **Enables new neutron, positron, x-ray and gamma ray sources**
- **Fusion ignition/thermonuclear**
- **Broaching, “make safe”**
- **Comms**
- **Beamed propulsion**
- **Materials processing and “machining”**
- **Medical applications**

Defense Against Air/Space Borne Swarms via Femto-Second Lasers

- **Continuous/cued surveillance of Environs via f-second lasers to find/illuminate/induce “fluorescence” of swarm elements**
- **Attrition via f-second laser slewing/ kill mechanisms/X-rays, improved atmospheric propagation and amplification from “channeling” CW laser**

NOTE: The anticipated reduced thermal/other inertia of swarm components compared to 20th Century munitions facilitates “take down/out” via f-second lasers.

Sampling of “Interesting” Technology Capabilities

- Factor of 5-to-8 Dry Wt. Red.- CNT's
- E8 more in computing-nano/molec/quantum
- Tb+ Bandwidth - optical
- 30%+ direct Conversion - Thermal to Elec.
- 50%+ PV
- Storable Positrons - E9 Xchem.
- Gamma Ray Lasers - Positrons
- SMES at 3Xchem - CNT Magnets
- H-B11 Fusion - aneutronic/safe
- Miniaturized, ultra-sensitive, ubiquitous, low power, multi-physics Sensors

Tech. Sampling [Continued]

- Non-Cryo H₂ Storage - Casimir Force designs
- Electron beam free form fabrication, Here & “There”
- Tethers for energy harvesting
- 300M to 1km + brilliant Membranes

Resulting Space System[s]

- Swarms of Miniaturized Payloads, resulting ubiquitous & inexpensive space access
- Huge apertures via smart membranes and Co-op conops - “Staring”
- Wonderous instrument etc. sensitivity , resolution, bandwidth
- Nav via Atom-optics,Pulsing cosmic X-Ray sources,optical GPS
- In-Space Beamers,Propulsion/orbit-raising and Ground/air/space Attack
- In-space fab/repair
- Monitoring of nano/RF tags, personal/onperson Electronics,wake vortices

In-Space Infrastructures?

- Fuel Depots, Tethers
- In-Situ Free Form fab & Repair/Service
- In-Space Beamers:
 - Lasers [50% solid state/FEL], MW - 50+% Monochromatic PV, Revolutionary Rectennas, concentrators/lenses
 - “Fueled”, PV, Isomer or Nuc [various e.g. vortex], E-M Tethers
 - Beamed energy for orbit raising, Maneuvering [$I_{sp} = 2500$ /MHD, sails], Asteroid defense, space debris
 - Atmospheric “dips” for “fuel”? [aerobrake manuev.]
 - Highly Vulnerable
 - “Dual Use” [Civilian, Commercial, Space ops/Anti-space/Ground Attack...]

Satellite Outlook[s]

- [Continued] Extreme size Reductions via IT, Micro/Nano, Energetics Technology Revolutions
- Wonderous AFFORDABLE Enhanced Functionality across-the-board
- Aperture via Co-operative Con-ops or Membranes

Leading to/providing:

- “Everymans” Space capability [\$50K fab & Launch, value/lb vice \$/lb]
- Global Sensor Grid
[Scientific/Commercial/Military]

Launch Vehicle Outlook[s]

- Reduced size/Multiple Payloads
- Automatic/autonomous ops [Reduced “standing Army Costs,IVHM]
- Reduced cost/Ruggedized “Conventional Rockets”
- Revolutionary Rockets [PDWR,Ejector,Beamed MWs/MHD,HEDM/Adv. Fuels,CNT Materials..]
- Micro/MEMS Rockets

Ongoing Changes/Options in Space Utilization & Economics

- From IT/Bio/Nano - Payloads which are much Smaller/Lighter/Smarter/Cheaper
- Results in increasing “Value per pound” and less pounds /costs for space access
- Decreasing rationale for “Humans in Space” (Robotics MUCH “better/cheaper/faster”)
- Revol. Rocket & “Mass Launch” Options
- Reusable In-Space Infrastructures (Fuel Depots, “Beamers,” Insitu free form fab.)

And Then There Is “Near Space”

- **Nominally 75k ft to 325k ft**
- **FAR Cheaper, “Faster”**
[development/deployment] and **“Better”** [e.g. **Resolution, Persistence**] than [TAC] **“Space”**
- **Buoyant Lift Problematical above ~ 90 k ft**
- **Fixed Wing[s] “work”, KEY IS
ENERGETICS/PROPULSION**
 - **Currently PV/Fuel Cells/Elec. Motors**
 - **Future options include Positrons, SMES/CNT
Magnetics, Soliton Energy Beaming, X10
improved Fuel Cells and X3 improved PV**

Space Tech “Futures”

Bottom Lines

- The ongoing IT/Nano/Energetics Tech Revolutions will Revolutionize SPACE Technology in terms of Capabilities/Size/Cost/Flexibility/Ubiquity
- There is an “Embarrassment of Riches” in terms of “Tech. Opportunities/options” with more added almost daily, needs to be Continuously Triaged - investigate 20 to get 2 or 3 really good ones [wide ranging metrics]
- World-Wide Technology/Capabilities

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“Frontiers of the *Responsibly Imaginable*”**

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