“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”?

Membrane Structures

- Lightweight/Deployable/Inflatable/Rigidable [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 keyes
- 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


• 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-B11 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............................................ $E_{108}$ X Chemical
- Anti-Matter/Positrons..... $E_{10}$ X Chemical
- Fission/Fusion...................... $E_{6}$ X Chemical
- Isomers................................. $E_{5}$ X Chemical
- SBER........................................ $E_{2}$ X Chemical
- Hydrogen.................................. $38$ KWH/Kg
- HC.......................................... $14$ “
- Advanced Flywheels.......... $.9 - 20?$ “
- Batteries............................... $.04 - 10?$ “
- SMES........................................ $0.0015 - \sim 100?$ “
- Super/ultra Capacitors......... $0.0007 - 8?$ “
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/”Net-works”

- 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

- Terrahertz
- 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
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 Propogation (< 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 Environments 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 [Isp = 2500 /MHD, sails], Asteroid defense, space debris
  - Atmospheric “dips” for “fuel”? [aerobrake maneuver.]
- 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 rational 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, Persistance] 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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