Kent Nebergall

FlexSail: Engineering Technology Revolutions



Introduction



Technology Revolutions

• History and Drivers

- Knowing when a technology goes from lab to life
- From following trails to building roads



FlexSail: Convergent Solar Sail Development

• Physics

- Electrical and Structural Engineering
- Genetic Algorithms



SECADS:

Lifecycle of Technology Revolutions

Ideas start at the top and work down.

Inventions start at the bottom (workbenches) and bounce back up.

STEM: Useful in Education, but Technically Wrong



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Convergence: Factorial Explosion

2!=2, 3!=6, 4!=24, 5!=120

Aircraft	RADAR	Voice Radio		
Basic Civil VFR planes Mail Planes	Weather Radar	Broadcast Radio, Television, Point-to-Point Radio Comms		
Observation aircraft Uncontrolled Airports		Aircraft radio relay		
Air Intercept, Early Warning (ground), All-weather (Transport) aircraft, Radar Navigation				
	Weather news in real time over broad area.			
Air traffic control, Defense interception, Weather Aircraft Safe airline transportation				
3 Inventions = 16+ Complex Systems				

History: Electric Motor



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Discovery or Invention	SECADS	Year	Creator
Static Drivers	1	1745	Ben Franklin
Battery Invented	2	1799	Alessandro Volta
Electromagnetism	1	1820	Hans Christian Oersted
Rotary Motion	2	1821	Michael Faraday
EM Coils	2	1827	Anyos Jedlik
Crude DC motors	2	1832	William Sturgeon
Practical Electric Motors	4	1834	Davenport, von Jacobi
DC Generator (dynamo)	3	1864	Antoino Pacinotti
Reversible	3	1867	Siemens
Commercial Generators	Д	1871	Zenobe Gramme
Practical AC motor	4	1885	Galileo Farraris
Electric Trolley	3	1887	Frank Sprague
Induction Motor	3	1887	Nicola Tesla
Three-phase induction motor	3	1889	Mikhail Debrovolsky
Electric Elevator	3	1892	
Electric Train (L- Chicago)	3	1892	
Lorentz Effect described	3	1895	Hendrik Lorentz
Reluctance Motor	4	2000	(many)

SECADS Chart: Electric Motor



History: Solar Sail



Discovery or Invention	SECADS	Year	Creator
Solar wind discovered, idea of "sails" invented.	1	1610	Kepler
Attitude Control (Mariner 10)	1.5	1973	NASA
Proposed in science fiction (A Mote in God's Eye)	1	1974	Niven, Pournelle
Practical photon sails proposed	1	1980	NASA
Magnetic Sail proposed	1	1988	Dana Andrews, Robert Zubrin
M2P2 Proposed	1	2000	Robert Winglee
Electric Sail Proposed	1	2006	Pekka Janhunen
Practical light sails flown in deep space, Earth orbit	2	2010	JAXA, NASA
Experiments in LEO	2	2015	Planetary Society
Dipole Drive Sail	1	2018	Robert Zubrin

SECADS Chart: Solar Sail





SECADS:

Applied to Solar Sailing

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Science: What Exists in Deep Space?

Light Driven

• 9 newtons per square kilometer



Proton Driven

- Dynamic pressure of 1.25 nanonewtons per square meter
- 6 million protons per cubic meter moving at 500 km/s



Field Driven

- Planetary and solar magnetic fields
- Particles trapped in those fields.

Engineering: What can we built?





Field Driven

- Electric Sail and Electrodynamic Tethers
- Magnetic Sail

Convergence: Concepts (Next Era)



Electric (X axis) + Magnetic (Y axis)

• Results in Lorentz Force at Z axis (MHD drive)



Pulsed Magnetic Array

- Equivalent to AC motor versus DC
- Can make a sort of phase array magnetic railgun



Plasma "Tossing"

- Generate a field that is self-sustaining, detached Loop
- Accelerate it away from the vehicle

"FlexSail": Modular Ribbon Workbench



Al Designed Car: Genetic Algorithm (Accelerated Convergence Optimization)





Al Design Iterations



Al Design Levels (minimum, ideal, flocks)



Modular Concept

- Single simple design (ribbon)
- Elements for mirrors, solar cells, magnets, and charged wires



Scaling Genetic Algorithm

- Rescale each element and reconfigure in system
- Use static interplanetary condition sets.



Modular Flock and Behavior Al

- Design system that can be used in fleets for propulsion and protection
- Using space weather data, simulate with "Flock" behavior to reconfigure en flight

Scale Prospects



Robotic Scale

- Fast Solar System Probes
- Solar Weather Research Fleet



Fleet Scale

- SpaceX Starship Fleet Solar Storm Shield Escort
- Asteroid Mining Fleets



Planetary Scale

- Carrigan Event Elliptical Polar Orbit Shield
- James Green Sun-Mars L1 Terraforming Solar Wind Shield

Augmenting the Magnetosphere



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Collaboration Requested



Physics

• Space Weather



Engineering

- Aerospace
- Genetic Algorithms
- Flow Simulation

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THANKS! Questions?

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