AEROSPACE PROPULSION INNOVATION

AEROSPACE – YOUR FUTURE 090112

This document has been reviewed by:
Nick Asch, Co-Founder & Chief Technical Officer
Gliph, https://gli.ph
AEP107 Alumni

NOTE: Please send all document improvement comments and Innovation updates to:
Tom Teel, tfteel@gmail.com
Thank You!

WELCOME

AEROSPACE PROPULSION INNOVATION

Aerospace – Your Future

One the simple four forces of flight is THRUST (propulsion). In today's world, engine and transportation efficiency is driving propulsion innovation to the limits and beyond. Periodically, there is news of the latest and greatest propulsion engine (innovation) that will beat the competitors.

This document provides background information on the aerospace industries propulsion innovation. Our old friend, THRUST FORCE.

PLEASE NOTE:
Propulsion Innovation is moving very quickly. Industry definitions / names / descriptions are not always in synch.

AEROSPACE PROPULSION INDUSTRY AT CROSSROADS

http://www.aviationweek.com/Article.aspx?id=/article-xml/asd_07_31_2012_p03-01-481555.xml
July 31, 2012, Guy Norris, *AVIATION WEEK*

ATLANTA — Space and air-breathing propulsion is at a "critical crossroads" in the face of shrinking budgets and fewer new program opportunities, NASA Acting Associate Administrator Robert Lightfoot says.
Speaking at the Joint Propulsion Conference here, Lightfoot says that to help counter these trends, the wider industry needs to be reminded about the criticality of propulsion technology as a whole.
"Here's my challenge: make propulsion relevant again. I think propulsion is being taken for granted. A lot of people don't realize how important it is in our daily lives. More than ever before, the propulsion is at a critical crossroads as we ask how we go forward."

AIRCRAFT ENGINE

Wikipedia, the free encyclopedia

Part of a series on Aircraft propulsion

Shaft engines :
driving propellers, rotors, ducted fans, or propfans

- *Internal combustion engines:*
- *Piston engine*
- *Wankel engine*
- *Turbines:*
  - *Turboprop*
  - *Turboshaft*
- *External combustion engines:*
  - *Steam-powered*

Reaction engines

- *Turbines:*
  - *Turbojet*
  - *Turbofan*
  - *Propfan*
- *Rocket-powered*
- *Motorjet*
- *Pulsejet*
- *Ramjet*
- *Scramjet*

Others

- *Human-powered*
- *Electric*
- *Nuclear*
- *Hydrogen*

*An **aircraft engine** is the component of the propulsion system for an aircraft that generates mechanical power. Aircraft engines are almost always either lightweight piston engines or gas turbines. This article is an overview of the basic types of aircraft engines and the design concepts employed in engine development for aircraft.*

To begin, what is old is made better with new technology and innovation:
We see examples of this in jet and reciprocal engine innovations that are being developed today.

JET ENGINES

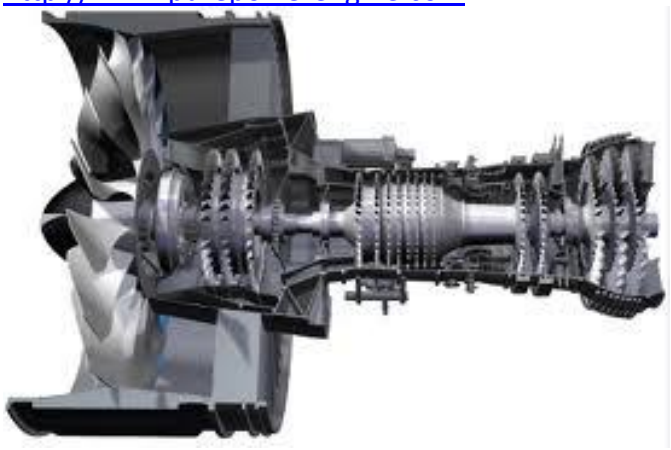
CFM AEROENGINES
LEAP TURBOFAN ENGINE
http://www.cfmaeroengines.com/engines/leap

The CFM LEAP-1B will be the exclusive powerplant for the Boeing 737 MAX family of single-aisle aircraft (737 MAX-7, 737 MAX-8, 737 MAX-9). This engine has been optimized to provide the 737 MAX the best possible fuel efficiency while maintaining the reliability and maintenance cost legacy of the CFM56 family. - CFM

GENERAL ELECTRIC
PASSPORT ENGINE
http://www.geaviation.com/bga/engines/passport.html

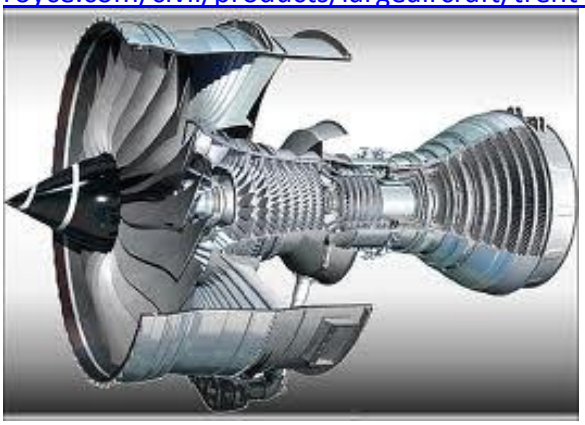
OVERVIEW
The GE Passport sets a new standard for performance of ultra-long range business aircraft. Developed as an Integrated Propulsion System (IPS), the Passport is designed to meet the requirements of the business aviation operator with low cabin noise, emissions and fuel consumption. As a result of rigorous testing and improvements across GE's military and commercial platforms, the Passport is poised to deliver enhanced performance, reliability and efficiency. - GE

PRATT & WHITNEY
PUREPOWER® PW1200G ENGINE
http://www.purepowerengine.com



OVERVIEW
The next-generation engine deserves next-generations service. You invested in the game-changing PurePower PW1000G engine for unmatched maturity, fuel efficiency and ease of maintenance. Now you want to keep your competitive advantage. No one knows our Geared TurboFan(tm) engines better than we do. With a view of the entire fleet of PurePower engines, we have the know-how and experience to help you get the most out of your asset.

ROLLS ROYCE
TRENT XWB
http://www.rolls-royce.com/civil/products/largeaircraft/trent_xwb

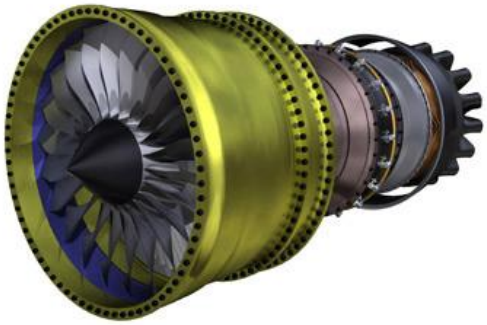


OVERVIEW
- Includes the latest technology for minimized operating costs
- Has single engine type operational benefits
- Will have the lowest carbon emissions of any widebody engine

The Trent XWB combines innovative proven Trent® design with world-class after-sales services

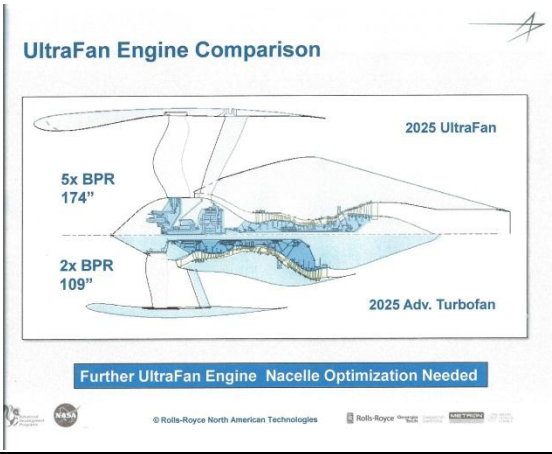
delivering the best power solution for the latest aircraft family from Airbus.

SAFRAN
SILVERCREST
http://www.safran-na.com/spip.php?rubrique25&lang=en



OVERVIEW
Developing 9,500 to 12,000 pounds of thrust, the Silvercrest engine is designed to power super-midsize to large business jets, and eventually regional jets with 40 to 60 seats. Its design was optimized to meet emerging requirements in the business aviation market. Among the many advantages of this new-generation engine are a simplified architecture, reduced parts count to cut maintenance cost, and lower specific fuel consumption. Environmental friendliness was also designed into the Silvercrest, which offers low noise and emissions.

NASA
ULTRA HIGH BYPASS RATIO ENGINE
The Promise and Challenges Of Ultra High Bypass Ratio Engine Technology and Integration
http://www.google.com/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&cad=rja&ved=0CCIQFjAA&url=http%3A%2F%2Fwww.aeronautics.nasa.gov%2Fpdf%2Fasm_presentations_promise_and_challenges1.pdf&ei=Huo3UILFDMWM7AGOu4HYCg&usg=AFQjCNGLDXXepBdlrapeSUlk6Vb012OoWQ&sig2=bTSetVbCYWjSokVPH5LjRQ



RECIPROCATING ENGINES

EcoMotors International
http://www.ecomotors.com
Opposed-Piston Opposed-Cylinder Engine

This patented design creates a ground-breaking internal combustion engine family architecture that will run on a number of different fuels, including gasoline, diesel and ethanol. The opoc's new opposed piston-opposed cylinder direct gas exchange operation provides the well known emissions benefit of 4-cycle engines, the simplicity benefits of 2-cycle engines, the power density of the less well known opposed piston engine, and the extraordinary developments in computer and thermodynamics all tied together in a new and proprietary engine architecture. It comprises two opposing cylinders per module, with a crankshaft between them, each cylinder has two pistons moving in opposite directions. This innovative design configuration eliminates the cylinder-head and valve-train components of conventional engines, offering an efficient, compact and simple core engine structure. The result is an engine family that is lighter, more efficient and economical, with lower exhaust emissions. Here you can see this revolutionary engine in operation, which helps to illustrate the simplicity, elegance and compactness of its design.

DIESEL ENGINE

FAIR DIESEL
http://www.fairdiesel.co.uk/technical.htm

***FairDiesel** Limited* has combined the concepts of barrel and opposed piston engines and applied them to produce an exceptionally well-balanced lightweight diesel engine for a wide range of applications.
The engine is shown diagrammatically, with opposed pistons acting on shaped cams through rollers.

An old idea that new technology caught up to:
We see examples of this in electric propulsion.

ELECTRIC
- **SOLAR ENERGY**
- **BATTERY**

ELECTRIC AIRPLANES FLYING INTO CENTER OF ATTENTION
30 Jul 2012, IDTech
http://evworld.com/news.cfm?newsid=28431

Uniquely, IDTechEx updates its reports on a continuous basis, so purchasers get the latest information. Nowhere is this more important than with electric aircraft in all their shapes and forms because progress is so rapid. For example, both the Germans and the Americans have been developing airliner nose wheels that make them electric vehicles when on the ground. No more waiting for the tug on landing and no belching of deafening megawatts while waiting to take off. The cost savings will be in millions of dollars a year and the noise and pollution reduction will be considerable. However, the latest news is that Boeing has won the race and, following trials, has ordered parts for several hundred airliners to be converted to use the power of their existing auxiliary power system APS to achieve this.

BATTERY

DISTRIBUTED TURBO ELECTRIC PROPULSION
- **EMBEDDED FAN**

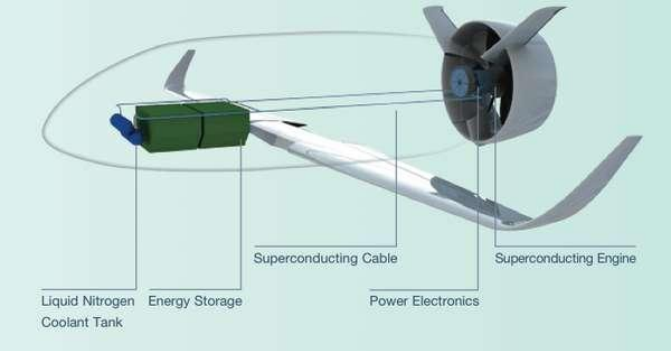
FUEL-SIPPER - THE TURBO-ELECTRIC FLYING WING
http://www.aviationweek.com/Blogs.aspx?plckBlogId=Blog:a68cb417-3364-4fbf-a9dd-4feda680ec9c&plckController=Blog&plckScript=blogScript&plckElementId=blogDest&plckBlogPage=BlogViewPost&plckPostId=Blog%253Aa68cb417-3364-4fbf-a9dd-4feda680ec9cPost%253Aea7a1fa9-2129-4c67-a93c-52ca6bda8e81
May 25, 2011, Graham Warwick
It will take some extreme measures to reduce fuel burn to more than 70% below that of today's GE90-powered Boeing 777-200LR - NASA's goal for an airliner entering service after 2030-35. So how about an all-composite, laminar-flow, hybrid wing-body (HWB) airframe with turboelectric distributed propulsion?

Graphics: NASA

Meet NASA's N3-X. This is the latest and most advanced evolution of NASA's HWB (a non-proprietary interpretation of Boeing's blended wing-body (BWB) configuration) - starting with the SAX-40 designed by the Cambridge-MIT Institute under the Silent Aircraft Initiative and evolving by way of the 2025-timeframe N2A and N2B configurations being wind tunnel-tested by NASA.

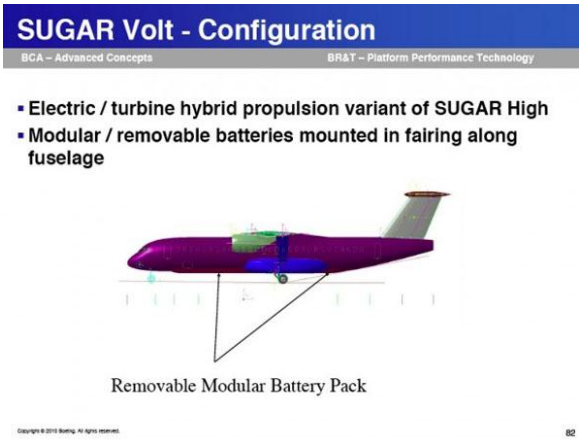
Turboelectric Distributed Propulsion in a Hybrid Wing Body Aircraft
http://naca.larc.nasa.gov/search.jsp?R=20120000856&qs=N%3D4294966788

EADS- VoltAir
http://www.eads.com/eads/int/en/our-innovation/our-technologies/Advanced-Concepts/VoltAir-concept.html
The desire to achieve a radical step change in commercial aviation also lies at the heart of the new VoltAir concept, which could become reality around 20 years from now. “This is a platform for future technologies that we have integrated into a well-balanced design of an overall aircraft system,” says Jan van Toor, Head of GIN5 Innovative Concepts and Long Term Scenarios at EADS Corporate Technical Office.



BOEING - SUGARVOLT
YOUTUBE:
http://www.youtube.com/watch?list=PL3727DD6718ECBEE6&v=oz3tzG9RxKI&feature=player_detailpage

BOEING:
http://www.boeing.com/stories/videos/vid_06_sugarvolt.html?cm_mmc=PaidSearch-Google-_-INNOVATIONS-_-Sugar+Volt+Unbranded-_-Electric+Planes



SOLAR ENERGY

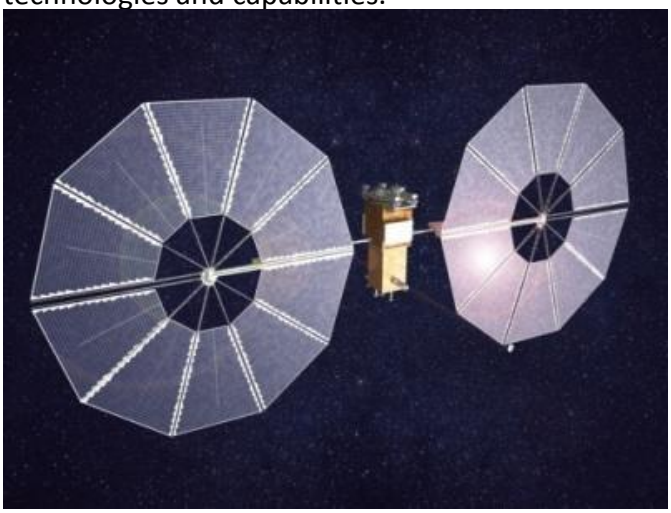
SOLAR IMPULSE
Solar Impulse tests solar-powered aircraft
August 16, 2012, Bret Williams

Solar energy is often considered for its uses for residential and commercial power. Like other forms of alternative energy, solar has been somewhat typecast into a very specific role. At one point, the energy has been considered viable for use in vehicles, but solar energy has since lost favor in terms of transportation. The use of solar energy in transportation had been largely confined to land-based vehicles, such as cars, which may have been the reason for its lack of popularity. Solar Impulse, a Swiss solar energy project, aims to bring solar energy into the realm of air travel.

BALL AEROSPACE
SOLAR ELECTRIC PROPULSION CONCEPT SUBMITTED TO NASA

A mission concept study has been submitted to NASA by Ball Aerospace & Technologies Corp. for demonstrating a solar electric propulsion (SEP) technologies in space. Ball Aerospace was one of five companies awarded up to $600,000 by NASA in September 2011, to formulate a mission concept to demonstrate the solar electric propulsion technologies, capabilities, and infrastructure required for sustainable and affordable human presence in space. NASA will use the studies to

plan and implement a future flight demonstration mission to test and validate those science technologies and capabilities.



"Ball Aerospace recognizes the mission enabling aspect of solar electric propulsion and our customer needs for SEP solutions," said Cary Ludtke, vice president of Ball's Civil and Operational Space business unit. "We believe we're the right-sized company with the right capabilities to take this space technology to the next level." - BALL

Bye Aerospace
Man Portable + Solar Powered (UAS | UAV)
http://www.satnews.com/cgi-bin/story.cgi?number=919970995
[SatNews] Bye Aerospace, in collaboration with Silent Falcon™ UAS Technologies, will feature the.....*Silent Falcon*™ solar electric unmanned aircraft system (UAS) at the Porsche Aircraft Experience at Denver jet Center on Centennial Airport August 16th. For more information, go to www.aircraftexperience.com. Bye Aerospace has provided engineering support to Silent Falcon™ UAS Technologies for the development of Silent Falcon™, a small tactical UAS designed to be man portable for longer-duration *intelligence, surveillance and reconnaissance* (ISR) missions. Silent Falcon™ employs proprietary technological advancements in aeronautical design; electrical propulsion systems, solar energy capture, storage and management; latest-generation electro-optical and infrared sensors; advanced target identification and tracking methodologies; and unique target image and data capture and transmission capabilities. The combined result is a tactical UAS and sensor system with capabilities that exceed any UAS in its size and weight class. Silent Falcon™ has progressed from ground to test flight, and orders are being accepted for the UAS and its FalconVision™ sensor package.

New technology that creates a game changer
We see examples of this in new types of propulsion units.

ADVENT ENGINE

(ADaptive **V**ersatile **EN**gine **T**echnology)
Wikipedia, the free encyclopedia

Cut-away view of a prospective ADVENT engine

The ADVENT program is an aircraft engine development program run by the United States Air Force with the goal of developing an efficient variable cycle engine for next generation military aircraft in the 20,000 lbf (89 kN) thrust class.

The objective of ADVENT is to develop an engine that is optimized for several design points, rather than the traditional single point. Instead of having an engine that is designed solely for high speed (like many current fighter engines are) or for high fuel efficiency (like many current commercial engines are), the final ADVENT engine would be designed to operate at both those conditions.[1] Specific goals include reducing average fuel consumption by 25% and reducing the temperature of cooling air produced by the engine.

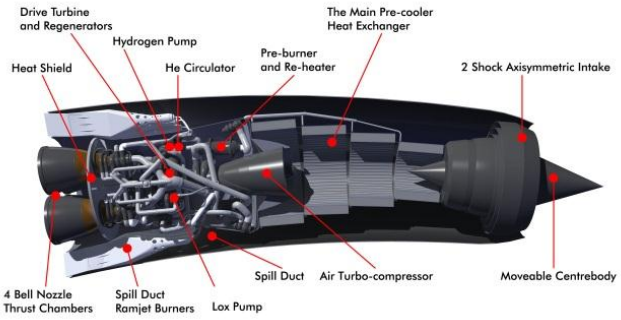
YOUTUBE:
http://www.youtube.com/watch?list=PL3727DD6718ECBEE6&v=oz3tzG9RxKI&feature=player_detailpage

REACTION ENGINES LIMITED

SABRE (Synergistic **A**ir-**B**reathing **R**ocket **E**ngine)[1]

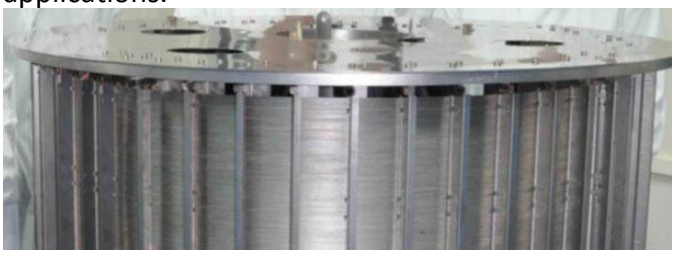
Wikipedia, the free encyclopedia

SABRE is a concept under development by Reaction Engines Limited for a hypersonic precooled hybrid air breathing rocket engine.[4] The engine has been designed to achieve single-stage-to-orbit capability, propelling the proposed Skylon launch vehicle. SABRE is an evolution of Alan Bond's series of liquid air cycle engine (LACE) and LACE-like designs that started in the early/mid-1980s for the HOTOL project.



REACTION ENGINES LIMITED:
http://www.reactionengines.co.uk

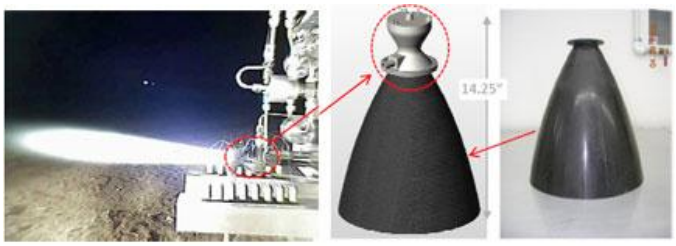
REL Heat Exchangers:
http://www.reactionengines.co.uk/heatex_rel.html
REL has developed the most powerful lightweight heat exchangers in the world. The breakthrough achieved will allow heat exchangers to be used for SABRE engines and a whole range of new applications.



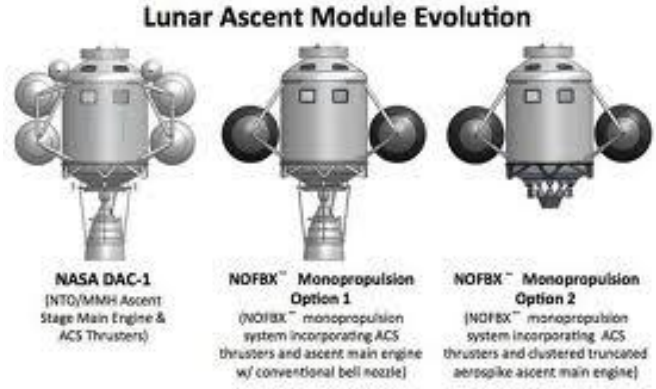
YOUTUBE:
http://www.youtube.com/watch?v=uZQqbM8Zfys&feature=player_detailpage

ROCKET PROPULSION

Innovative Space Propulsion Systems
http://ispsllc.com



NOFBX™ from ISPS – the Future of Propulsion Technology



NOFBX™ technology from ISPS offers bipropellant performance with technical simplicity beyond that of other monopropellants. Unlike other "green" propellant options, NOFBX™ delivers robust, reliable performance – and lower-cost. Importantly, the high thrust-to-weight ratio, deep throttling capability and low cost of NOFBX™ thrusters makes them highly adaptable, allowing them to be used as-is in a wide range of applications, including:

- Satellites and Other Spacecraft
- Cargo and Crew Transportation Vehicles
- Launch Systems
- Advanced Concepts and R&D Vehicles

Then there are **CONCEPTS** that are out there in research land. These are great ideas that need to be developed and "proven in" for real world operations.

ANEUTRONIC FUSION

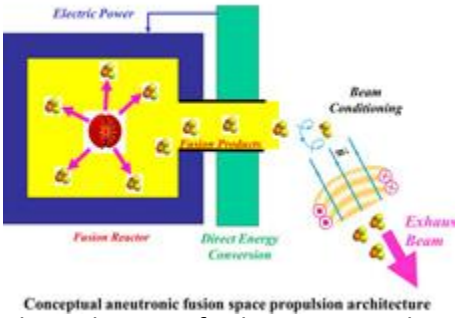
Wikipedia, the free encyclopedia

Aneutronic fusion is any form of fusion power where neutrons carry no more than 1% of the total released energy.[1] The most-studied fusion reactions release up to 80% of their energy in neutrons. Successful aneutronic fusion would greatly reduce problems associated with neutron radiation such as ionizing damage, neutron activation, and requirements for biological shielding, remote handling, and safety.

Some proponents also see a potential for dramatic cost reductions by converting energy directly to electricity. However, the conditions required to

harness aneutronic fusion are much more extreme than those required for the conventional deuterium–tritium (DT) fuel cycle.

NASA
ANEUTRONIC FUSION SPACECRAFT ARCHITECTURE
http://www.nasa.gov/offices/oct/early_stage_innovation/niac/tarditi_aneutronic_fusion.html
Alfonso Tarditi, University of Houston at Clear Lake

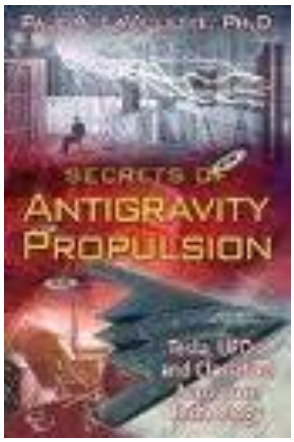


Conceptual aneutronic fusion space propulsion architecture

The object of this proposal is to conduct a feasibility study for a novel, fusion-powered, space propulsion architecture that can ultimately change drastically the potential for human and robotic space exploration. The proposed design is based on neutron-free nuclear fusion as the primary energy source. An innovative beam conditioning/nozzle concept enables useful propulsive thrust directly from the fusion products, while some fraction of the energy is extracted via direct conversion into electricity for use in the reactor and spacecraft systems.

ANTIGRAVITY

Wikipedia, the free encyclopedia
http://en.wikipedia.org/wiki/Anti_gravity
Anti-gravity is the idea of creating a place or object that is free from the force of gravity. It does not refer to the lack of weight under gravity experienced in free fall or orbit, or to balancing the force of gravity with some other force, such as electromagnetism or aerodynamic lift. Anti-gravity is a recurring concept in science fiction, particularly in the context of spacecraft propulsion. An early example is the gravity blocking substance "Cavorite" in H. G. Wells' *The First Men in the Moon*.



ANTIMATTER

Wikipedia, the free encyclopedia
http://en.wikipedia.org/wiki/Anti_matter
In particle physics, antimatter is material composed of antiparticles, which have the same mass as particles of ordinary matter but have opposite charge and quantum spin. Antiparticles bind with each other to form antimatter in the same way that normal particles bind to form normal matter. For example, a positron (the antiparticle of the electron, with symbol e+) and an antiproton (symbol p) can form an antihydrogen atom. Furthermore, mixing matter and antimatter can lead to the annihilation of both, in the same way that mixing antiparticles and particles does, thus giving rise to high-energy photons (gamma rays) or other particle–antiparticle pairs. The result of antimatter meeting matter is an explosion

NASA
New and Improved Antimatter Spaceship for Mars Missions
04.14.06
Most self-respecting starships in science fiction stories use antimatter as fuel for a good reason – it's the most potent fuel known. While tons of chemical fuel are needed to propel a human mission to Mars, just tens of milligrams of antimatter will do (a milligram is about one-thousandth the weight of a piece of the original M&M candy).

Image: A spacecraft powered by a positron reactor would resemble this artist's concept of the Mars Reference Mission spacecraft. Credit: NASA

However, in reality this power comes with a price. Some antimatter reactions produce blasts of high energy gamma rays. Gamma rays are like X-rays on steroids. They penetrate matter and break apart molecules in cells, so they are not healthy to be around. High-energy gamma rays can also make the engines radioactive by fragmenting atoms of the engine material.

CERAMIC ENGINE

EXPERTS CLAIM CERAMIC ENGINE IS FUTURE OF AVIATION
http://www.suasnews.com/2012/05/15750/experts-claim-ceramic-engine-is-future-of-aviation
17 May 2012, Sergio Prostak, Science

Aerospace engineering experts Drs Omid Gohardani and Amir S. Gohardani have proposed a novel aerospace propulsion concept for future greener transportation.
Their study, published in the journal *Aircraft Engineering and Aerospace Technology*, identifies a number of useful scenarios for future ceramic engine application, including a synergistic combination of the ceramic engine with a hybrid configuration of an airship and a flying wing called GUAV.

EMERALD INSIGHT:
http://www.emeraldinsight.com/journals.htm?articleid=17021645&show=abstract

CONTINUOUS DETONATION ENGINE

Wikipedia, the free encyclopedia
http://en.wikipedia.org/wiki/Pulse_detonation_engine

AERODYNAMICS RESEARCH CENTER
http://arc.uta.edu/research/cde.htm

ELECTROMAGNETIC PROPULSION

NASA
Magnetoplasmadynamic Thrusters
Once existing only in the realm of science fiction, electric propulsion has proven to be an excellent option for the future of space exploration. The magnetoplasmadynamic (MPD) thruster is currently the most powerful form of electromagnetic propulsion. The MPD's ability to efficiently convert megawatts of electric power into thrust makes this technology a prime candidate for economical delivery of lunar and Mars cargo, outer planet rendezvous, and sample return, and for enabling other bold new ventures in deep space robotic and piloted planetary exploration. With its high exhaust velocities, MPD propulsion offers distinct advantages over conventional types of propulsion for each of these mission applications. MPDs expel plasma to create propulsion. MPDs can process more power and create more thrust than any other type of electric propulsion currently available, while maintaining the high exhaust velocities associated with ion propulsion.

NASA Creates Electromagnetic Propulsion System Prototype
http://news.softpedia.com/news/NASA-Creates-Electromagnetic-Propulsion-System-Prototype-122124.shtml
Sep 19th, 2009, Tudor Vieru

Electromagnetic propulsion
Wikipedia, the free encyclopedia

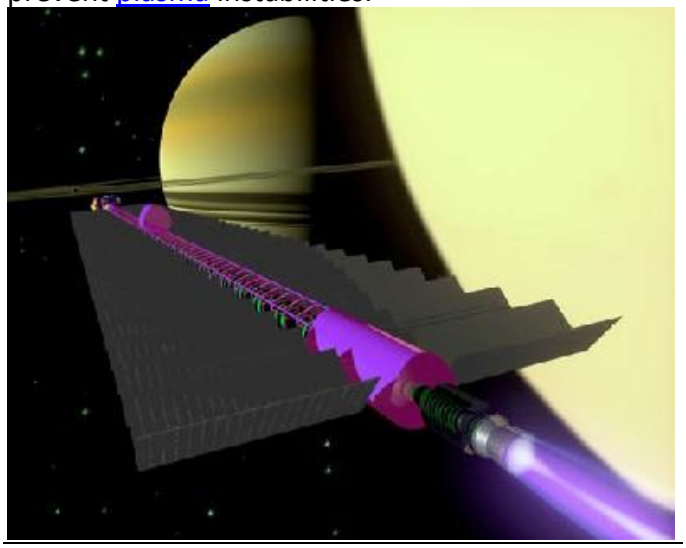
http://en.wikipedia.org/wiki/Electromagnetic_propulsion
Electromagnetic propulsion (EMP), is the principle of accelerating an object by the utilization of a flowing electrical current and magnetic fields. The electrical current is used to either create an opposing magnetic field, or to charge a fluid, which can then be repelled. It is well known that when a current flows through a conductor in a magnetic field, an electromagnetic force known as a Lorentz force, pushes the conductor in a direction perpendicular to the conductor and the magnetic field. This repulsing force is what causes propulsion in a system designed to take advantage of the phenomenon. The term electromagnetic propulsion (EMP) can be described by its individual components: electromagnetic- using electricity to create a magnetic field (electromagnetism), and propulsion- the process of propelling something. One key difference between EMP and propulsion achieved by electric motors is that the electrical energy used for EMP is not used to produce rotational energy for motion; though both use magnetic fields and a flowing electrical current.

How Electromagnetic Propulsion Will Work
Kevin Bonsor
http://science.howstuffworks.com/electromagnetic-propulsion.htm
When cooled to extremely low temperatures, electromagnets demonstrate an unusual behavior: For the first few nanoseconds after electricity is applied to them, they vibrate. David Goodwin, a program manager at the U.S. Department of Energy's Office of High Energy and Nuclear Physics, proposes that if this vibration can be contained in one direction, it could provide enough of a jolt to send spacecraft farther and faster into space than any other propulsion method in development.

FUSION PROPULSION

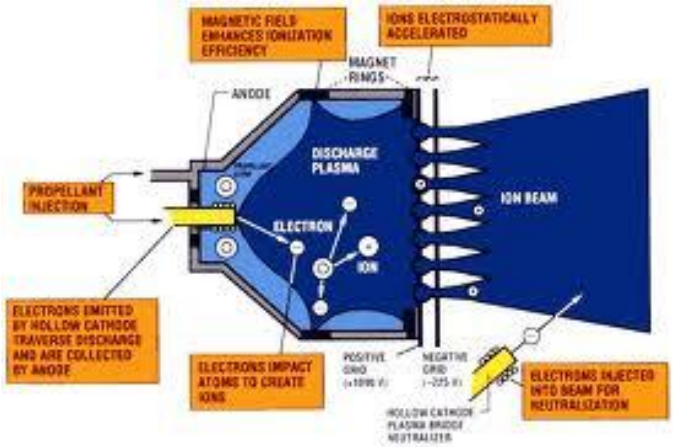
HOW STUFF WORKS
How Fusion Propulsion Will Work
http://www.howstuffworks.com/fusion-propulsion.htm
Kevin Bonsor
Basically, fusion-powered spacecraft are designed to recreate the same types of high-temperature reactions that occur in the core of the sun. The enormous energy created from those reactions is expelled from the engine to provide thrust. Using this type of propulsion system, a spacecraft could speed to Mars in just about three months. It would take conventional rockets at least seven months to reach Mars.

Fusion rocket
From Wikipedia, the free encyclopedia
http://en.wikipedia.org/wiki/Fusion_rocket
A **fusion rocket** is a theoretical design for a rocket driven by fusion power which could provide efficient and long-term acceleration in space without the need to carry a large fuel supply. The design relies on the development of fusion power technology beyond current capabilities, and the construction of rockets much larger and more complex than any current spacecraft. A smaller and lighter fusion reactor might be possible in the future when more sophisticated methods have been devised to control magnetic confinement and prevent plasma instabilities.



ION PROPULSION

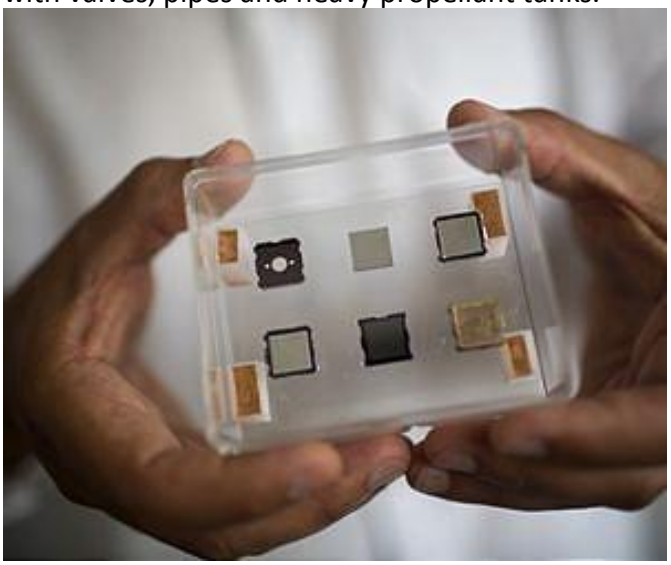
NASA
OVERVIEW
http://www.nasa.gov/centers/glenn/about/fs21grc.html



MICROTHRUSTERS

MIT-developed 'microthrusters' could propel small satellites

http://www.spacedaily.com/reports/MIT_developed_microthrusters_could_propel_small_satellites_999.html
Aug 21, 2012, Jennifer Chu, MIT News, Boston MA
A penny-sized rocket thruster may soon power the smallest satellites in space. The device, designed by Paulo Lozano, an associate professor of aeronautics and astronautics at MIT, bears little resemblance to today's bulky satellite engines, which are laden with valves, pipes and heavy propellant tanks.



The different components that make up the MIT microthruster

NUCLEAR PROPULSION

Wikipedia, the free encyclopedia
http://en.wikipedia.org/wiki/Aircraft_Nuclear_Propulsion
The Aircraft Nuclear Propulsion (ANP) program and the preceding Nuclear Energy for the Propulsion of Aircraft (NEPA) project worked to develop a nuclear propulsion system for aircraft. The United States Army Air Force initiated Project NEPA on May 28, 1946.[1] After funding of $10 million in 1947,[2] NEPA operated until May 1951, when the project was transferred to the joint Atomic Energy Commission (AEC)/USAF ANP.[3] The USAF pursued two different systems for nuclear powered jet engines, the Direct Air Cycle concept which was developed by General Electric, and Indirect Air Cycle which was assigned to Pratt & Whitney. The program was intended to develop and test the Convair X-6, but was cancelled in 1961 before that aircraft was built.[4]

August 19, 2012
NASA Proposal to Revive Nuclear Thermal Space Propulsion Development

Nuclear Thermal Rocket Propulsion for Future Human Exploration Missions (24 pages)

OPEN ROTOR

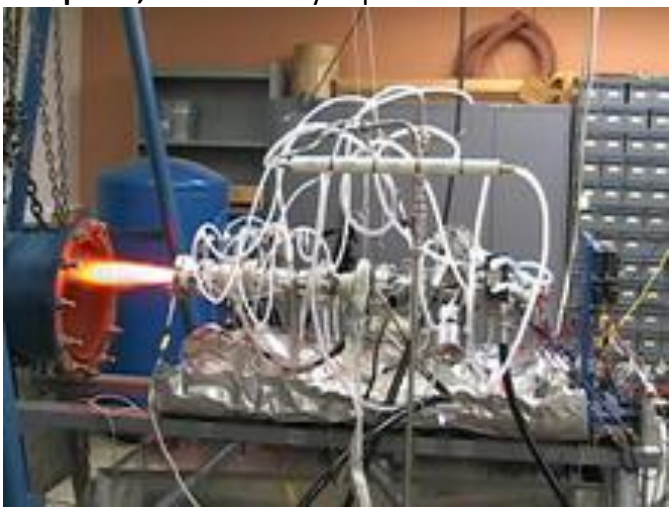
SAFRAN - OVERVIEW

Achieving a satisfactory solution means striking the optimum tradeoff between certain contradictory requirements. For example:

- Increasing the bypass ratio decreases engine noise, but also makes it larger, which means greater weight, drag and …. fuel consumption.
- An open-rotor type engine would lower fuel consumption by 20 to 25%, but is also noisier.
- Consumption (and therefore CO2) can be reduced by increasing the compression ratio, and therefore the combustion temperature, which in turn generates more oxides of nitrogen, or NOx.

PULSE DETONATION ENGINE

Wikipedia, the free encyclopedia



A pulsed detonation engine ground demonstrator operating at a frequency of 35 Hz. Ground demonstrator engines are subject to intense heating, creating the need for active water cooling of this engine. Fuel and oxidizer are supplied to the engine using a valving system that matches with the operating frequency.
A pulse detonation engine, or "PDE", is a type of propulsion system that uses detonation waves to combust the fuel and oxidizer mixture.[1][2] The

engine is pulsed because the mixture must be renewed in the combustion chamber between each detonation wave initiated by an ignition source. Theoretically, a PDE can operate from subsonic up to a hypersonic flight speed of roughly Mach 5. An ideal PDE design can have a thermodynamic efficiency higher than other designs like turbojets and turbofans because a detonation wave rapidly compresses the mixture and adds heat at constant volume. Consequently, moving parts like compressor spools are not necessarily required in the engine, which could significantly reduce overall weight and cost. PDEs have been considered for propulsion for over 70 years.[3] Key issues for further development include fast and efficient mixing of the fuel and oxidizer, the prevention of autoignition, and integration with an inlet and nozzle.

AEROSPACE RESEARCH CENTER:
http://arc.uta.edu/research/cde.htm
The PDE is a propulsion system that has been receiving considerable interest in the last decade, due to the numerous advantages that it offers over traditional jet engines. PDEs operate in an intermittent cyclical manner, by giving rise to detonation waves that combust the fuel-oxidizer mixture within the engine, release vast amounts of energy and develop much higher pressures than a deflagration process.

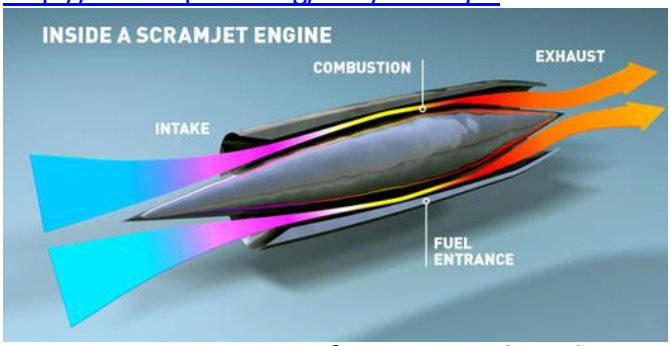
REACTIONLESS DRIVE

Wikipedia, the free encyclopedia
http://en.wikipedia.org/wiki/Reactionless_drive
A reactionless drive (also known by many other names, including as an *inertial propulsion engine*, a *reactionless thruster*, a *reactionless engine*, a *bootstrap drive* or an *inertia drive*) is a fictional or theorized method of propulsion wherein thrust is generated without any need for an outside force or net momentum exchange to produce linear motion. The name comes from Newton's Third Law of Motion, which is usually expressed as, "[f]or every action, there is an equal and opposite reaction". Such a drive would necessarily violate the law of conservation of momentum, a fundamental principle of all current understandings of physics. In addition, it can be shown that the law of conservation of energy would be violated by a reactionless drive.
In spite of their physical impossibility, such devices are a staple of science fiction, particularly for space propulsion, and as with perpetual motion machines, have sometimes been proposed as working technologies.

(Photo: MIT)

SCRAMJET
Supersonic **C**ombustion **Ramjet**

Wikipedia, the free encyclopedia
http://en.wikipedia.org/wiki/Scramjet

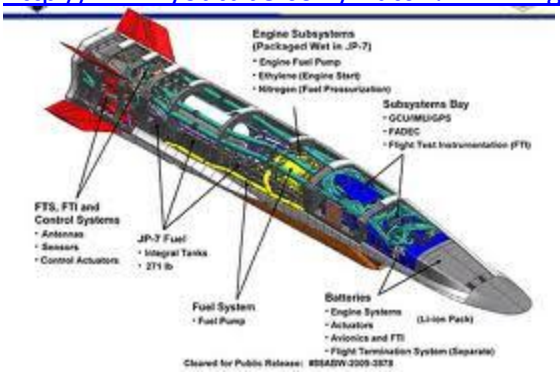


A scramjet is a variant of a ramjet airbreathing jet engine in which combustion takes place in supersonic airflow. As in ramjets, a scramjet relies on high vehicle speed to forcefully compress and decelerate the incoming air before combustion (hence *ram*jet), but whereas a ramjet decelerates the air to subsonic velocities before combustion, airflow in a scramjet is supersonic throughout the entire engine. This allows the scramjet to efficiently operate at extremely high speeds: theoretical projections place the top speed of a scramjet between Mach 12 (9,100 mph; 15,000 km/h) and Mach 24 (18,000 mph; 29,000 km/h). The fastest air-breathing aircraft is a SCRAM jet design, the NASA X-43A which reached Mach 9.6. For comparison, the second fastest[1] air-breathing

aircraft, the manned SR-71 Blackbird, has a cruising speed of Mach 3.2 (2,100 mph).[2]

Brazilian Scramjet

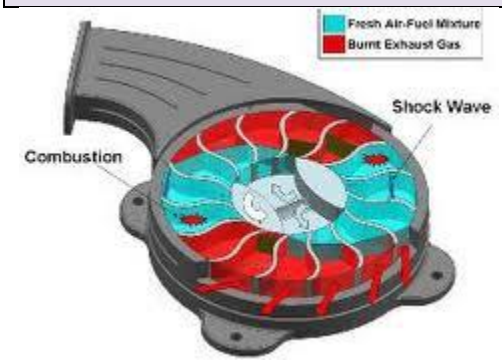
YOUTUBE: SCRAMJET OPERATIONS
http://www.youtube.com/watch?v=fHRwgf4px9w



STEAM PROPULSION

http://www.purco.qc.ca/ftp/Romanian/Aerospace%20propulsion/7a,-Generatorul%20Vuia-3.JPG

WAVE DISK ENGINE



WIKIPEDIA, THE FREE ENCYCLOPEDIA

A **wave disk engine** (wave disk generator) is a type of pistonless rotary engine being developed at Michigan State University and Warsaw Institute of Technology. The engine has a spinning disk with curved blades. Once fuel and air enter the engine the rotation of the disk creates shockwaves that compress the mixture. When ignited, the burning mixture expands, pushing against the blades, causing them to spin. The spinning of the disk itself opens and closes intake and exhaust ports.[1] The proposed concept was called Radial Internal Combustion Wave Rotor.

PROPULSION ENERGY TECHNOLOGY

ALTERNATIVE FUELS FOR AVIATION

NASA
http://www.energybulletin.net/node/23098
D. Daggett, O. Hadaller, R. Hendricks, and R. Walther

Abstract

With a growing gap between the growth rate of petroleum production and demand, and with mounting environmental needs, the aircraft industry is investigating issues related to fuel availability, candidates for alternative fuels, and improved aircraft fuel efficiency.

Bio-derived fuels, methanol, ethanol, liquid natural gas, liquid hydrogen, and synthetic fuels are considered in this study for their potential to replace or supplement conventional jet fuels. Most of these fuels present the airplane designers with safety, logistical, and performance challenges.

Synthetic fuel made from coal, natural gas, or other hydrocarbon feedstock shows significant promise as a fuel that could be easily integrated into present and future aircraft with little or no modification to current aircraft designs.

Alternatives, such as biofuel, and in the longer term hydrogen, have good potential but presently appear to be better suited for use in ground transportation. With the increased use of these fuels, a greater portion of a barrel of crude oil can be used for producing jet fuel because aircraft are not as fuel-flexible as ground vehicles.

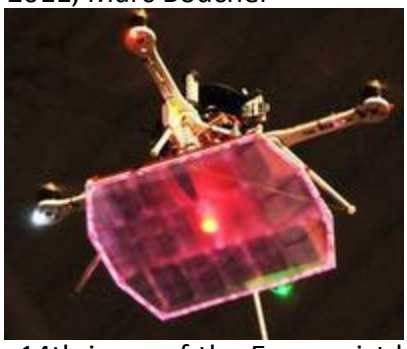
EADS
http://www.eads.com/eads/int/en/news/dossiers/Alternative-Fuels.html

BEAM-POWERED PROPULSION

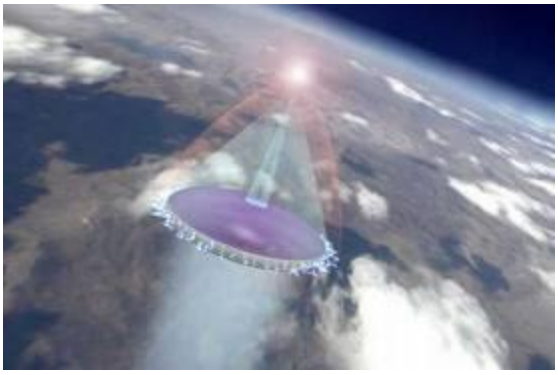
WIKIPEDIA, THE FREE ENCYCLOPEDIA

Beam-powered propulsion is a class of aircraft or spacecraft propulsion mechanisms that use energy beamed to the spacecraft from a remote power plant to provide energy. Most designs are rocket engines where the energy is provided by the beam, and is used to superheat propellant that then provides propulsion, although some obtain propulsion directly from light pressure acting on a light sail structure, and at low altitude heating air gives extra thrust.

http://www.spaceelevator.com/beam-power-technology
March 11, 2011, Marc Boucher



The March 14th issue of the Economist has a good article on bean power technology titled Beam it up, "*Energy: Laser beams can deliver energy to machines through thin air. This might be a good way to power drone aircraft or a space elevator.*" This will no doubt bring more awareness to one aspect of the a future space elevator system**.**



The basic idea behind light propulsion is the use of ground-based lasers to heat air to the point that it explodes, propelling the spacecraft forward. If it works, light propulsion will be thousands of times lighter and more efficient than chemical rocket engines, and will produce zero pollution.

LASER
Wikipedia, the free encyclopedia
http://en.wikipedia.org/wiki/Laser_light
A **laser** is a device that emits light (electromagnetic radiation) through a process of optical amplification based on the stimulated emission of photons. The term "laser" originated as an acronym for *Light Amplification by Stimulated Emission of Radiation*.[1][2] The emitted laser light is notable for its high degree of spatial and temporal coherence

MICROWAVE PROPULSION
http://library.thinkquest.org/03oct/02144/propulsion/microwave.htm
The microwave light craft is equipped with two powerful magnets and three types of propulsion engines. Large number of antennas, built on the top of the craft, receives microwaves and converts it into electricity required for launching. The electricity produced ionizes the air and propels the craft forward.

FUEL CELL PROPULSION

VIDEO:
http://www.nasa.gov/multimedia/videogallery/index.html?media_id=151037381

BOEING AND OTHER PARTNERS CREATE THE FIRST HYDROGEN FUEL CELL POWERED AIRPLANE

Mar 29th 2007, Jeremy KorzeniewskiRSS feed
Boeing is getting an early start on what it sees as a possible emerging market, that of hydrogen fuel cell powered electric airplanes. They have created an electric airplane which generates its electricity from a fuel cell. The machine is a standard propeller driven plane with a 53.5 foot wingspan which was converted to store the lithium ion batteries, the fuel cell and the hydrogen storage tanks. During takeoff, where the highest draw of power is required, the lithium ion batteries provide the power to the motor, and at constant cruising speed of 62 mph, the Proton Exchange Membrane fuel cell provides the power.

BOEING'S CORPULENT HYDROGEN-POWERED DRONE MAKES ITS FIRST FLIGHT
06.05.2012, Rebecca Boyle
http://www.youtube.com/watch?NR=1&v=VQB5MBHbLrM&feature=endscreen

PhantomEye in FlightBoeing

Eventually it will fly for four days straight, making only water as its waste product. But a journey of four days starts with a few minutes, so the chubby PhantomEye's first autonomous flight was under half an hour.

GREEN ROCKET PROPELLANT

Ball Aerospace Leads Green Propellant Technology Demonstration Mission for NASA
http://www.sacbee.com/2012/08/21/4744766/ball-aerospace-leads-green-propellant.html
BOULDER, CO, Aug. 21, 2012 -- /PRNewswire/ -- Ball Aerospace & Technologies Corp. has been awarded a contract from NASA to lead a government-industry team in the demonstration of an alternative fuel option for future space vehicles. The Ball team will develop and fly the Green Propellant Infusion Mission (GPIM) to demonstrate a high-performance, non-toxic fuel alternative to conventional hydrazine. The mission will demonstrate and characterize the functionality of an integrated propulsion system to bridge the gap between technology development and actual use of green propellant in space.