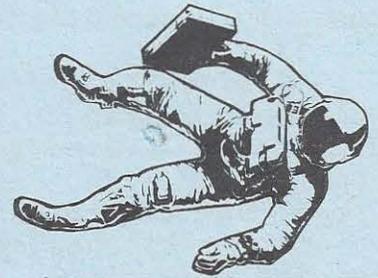


THE
**COMMERCIAL
SPACE REPORT**



PUBLISHED MONTHLY

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Dear Subscriber:

January 1982

Advanced Propulsion Systems Update: The Antimatter Rocket. One of the most critical areas of commercial space transportation involves the type of propulsion system used on the spacecraft or launch vehicle. Most of the other characteristics of the spacecraft such as mission cost, reusability, location of launch and landing facilities, or even whether the system can perform a mission at all, depend on propulsion.

Most existing systems and designs utilize some form of chemical engine. These range from the "Big Dumb Booster" type of low-pressure engine to the complex, high-pressure Space Shuttle Main Engine. However, future space vehicles will require far more advanced methods of propulsion to handle the high-velocity lunar and planetary missions that will be necessary for the exploitation of resources in space.

The Report has mentioned some advanced propulsion concepts in previous issues (April, 1978 and May, 1979), but new information and new ideas keep rolling in.

One way to keep abreast of what's going on in the space propulsion field is to attend, or collect papers from, the annual AIAA/SAE/ASME Joint Propulsion Conference. The 17th version was held in Colorado Springs last July, and some interesting concepts appeared in some of the papers presented there. At least two new papers concerned advanced ideas on the concept of the antimatter powered rocket.

First, a short review. The major method of measuring a rocket's efficiency is via its specific impulse. This is simply a number, measured in "seconds", which tells you how much propellant a rocket must burn to get a certain performance. For example, a rocket with a specific impulse (Isp for short) of 250 seconds (very typical for a chemical rocket) would burn 1 pound of fuel to produce 1 pound of thrust for 250 seconds, or some other such combination like 1 pound of fuel for 2 lbs. thrust for 125 seconds. A high-performance chemical engine can reach over 500 seconds of specific impulse. Can we do better than this? Of course. Ion engines have much higher impulses, and already have been constructed. There is one catch, though. An ion engine's thrust is very small, usually measured in fractions of an ounce. A fusion rocket whose only exhaust was the subatomic particles produced by the reaction would have an Isp of over 3 million seconds. Yet for those subatomic particles to create a reasonable thrust would require an enormous fusion system of near perfect efficiency. If you switch on a flashlight, you hold in your hand a working photon rocket, one which uses light as its exhaust. This flashlight possesses the highest attainable specific impulse, over 30 million seconds. Thrust? There's that catch again. Measuring the thrust pro-

duced by a flashlight would take very sophisticated instruments indeed.

Yet, working concepts have been proposed for high thrust systems. What is required to produce them? The easiest method is to use a standard rocket tradeoff: thrust for specific impulse. If something is done to increase the mass of the exhaust, the efficiency of the engine drops, but the thrust increases. This is normally done by injecting an inert substance, often hydrogen or water, into the combustion chamber (or reactor, in the case of a nuclear system) and allowing the reaction to heat the substance and add it to the exhaust. More thrust, lower specific impulse. Since chemical rockets usually start out with a high-mass exhaust product, this is not often required. With systems such as nuclear, with reaction products that are subatomic particles, this method works exceedingly well. Hence, most designs for nuclear rockets involve injecting a propellant into the reactor to produce the exhaust. Although this drastically reduces the specific impulse, the so-called "low" Isp that results is still far higher than that attainable by chemical engines, and allows a more reasonable thrust level comparable to those same chemical engines.

Now, back to the antimatter rocket. Until recently, most designs for matter-antimatter concepts involved equal amounts of matter and antimatter which would react to form a beam of high-energy photons. This would be reflected out the back to produce a photon rocket with its 30-million-second Isp. Ideally, no vehicle which operates by carrying its own fuel along can be more efficient than such a system.

Yet, here the concept begins to break down. First, the matter-antimatter reaction is not as clean as you might suppose. The two basic reactions are: electron + positron (or antielectron) \rightarrow 2 photons (with sufficient energy to be called gamma ray photons), and proton + antiproton \rightarrow pions, which decay through several steps into more gamma photons, some electrons, some positrons, and a few neutrinos. If the electrons and positrons can be held onto long enough to react, the end product would indeed be a pure beam of photons and neutrinos. Of course, in a reactor of finite size, many of the initial reaction particles would either escape or be absorbed by the walls before decaying.

Even if the reactions can be controlled to produce a pure photon rocket, the problems are not yet over. The photons are in the form of gamma rays. Reflecting these into a beam requires a material that will reflect gamma rays with a minimum of absorption. Such materials are rare. (It goes without saying that trying to reflect a neutrino is a non-trivial problem at best. Forget them.) Even the best reflective materials will absorb a certain amount of gamma rays. They are highly penetrating. How much is too much? In dealing with a pure photon rocket, we are dealing again with a high-Isp vs. a low-thrust situation. Well, we want the higher thrust levels, so we beef up the engine. A 100,000 lb. thrust photon rocket kicks out a two-million megawatt beam of gamma radiation. (In contrast, a Space Shuttle Main Engine, an extremely powerful chemical engine, produces three times this thrust at less than 0.3% of this power level--and the exhaust is water, not gamma rays) Clearly, even a small percentage of this photon engine's power deposited into the walls of the reaction chamber will be a serious problem.

Yet another problem. The so-called "pure" antimatter (photon) rocket requires equal amounts of matter and antimatter. This means that a fuel load of 500,000 lbs. would require 250,000 lbs. of antimatter. Antimatter is going to be hard to get, no matter what advanced manufacturing methods are used. This is going to be an

expensive fuel load. Do we need 30 million seconds that badly? If we are planning an interstellar flight, yes, it would help a great deal. But what about interplanetary and lunar applications? Can we do something to bring the photon rocket closer to some kind of commercial feasibility? Well, as hinted earlier, and mentioned in the Report articles referred to previously, there is a way.

Dr. Robert Forward suggested in 1975 that a "dilute" antimatter rocket, one which utilized a separate propellant injected into the reaction chamber, might have fewer problems than a "pure" or photon-type of antimatter rocket. In one of the papers from the Joint Propulsion Conference, Design Considerations For Relativistic Antimatter Rockets by B.N. Cassenti, this is gone into in some detail. Comparison of "pure" and "diluted" systems show advantages to the "diluted" system. First, the fuel load now consists mostly of inert propellant, like liquid hydrogen. As little as 1% of antimatter reacting with this propellant can produce a rocket which is much less efficient than a photon rocket, but still has a specific impulse in the millions range. You can build a hell of a nice spaceship around an engine like that, and your 500,000 lb. fuel load now has only 5000 lb. of antimatter.

Second, the aforementioned tradeoff of impulse vs. thrust will give more reasonable thrust levels at lower total power outputs. For operations in lunar and planetary environments, high thrust is critical for rapid operations and ability to take off and land directly on planetary surfaces.

Thirdly, the lower power output means less problems with the huge energy fluxes of a pure photon rocket. It is also easier to direct a chemical propellant than a beam of gamma radiation.

The tradeoff is not so bad, either. Although a "pure" photon exhaust antimatter spacecraft would have a mass ratio (fuel wt. + spacecraft wt. / spacecraft wt.) approaching 1.0 (that is, hardly any fuel required for a low-velocity mission), a "dilute" system's mass ratio would probably be less than 10 for even a high-velocity mission.

Did I mention that 5000 lb. of antimatter would be cheaper than 250,000 lbs.? That may be the most important factor of all. 5000 lbs. is also easier to store and handle.

Production and handling have always been the stickiest areas of antimatter propulsion. A second paper, Technology Assessment of Photon Propulsion: How Close Are We? by J.H. Wickman, may be a partial answer to this remaining difficulty.

Wickman points out that most standard methods of antimatter production involve large accelerators that produce tiny amounts of anti-protons. He shows that certain elements have positrons (antielectrons) as natural radioactive decay products. It is shown that a relatively small quantity of such elements could produce enough positrons to power a relatively large antimatter engine. This would allow the spacecraft to carry its antimatter production system along with it, producing only as much antimatter as is needed at any given time. This alleviates many of the production and storage problems of other concepts.

Still, Wickman is operating under the assumption that the spacecraft will be a pure photon rocket. (as you recall, the electron-positron reaction produces only photons). Yet, even though he assumes he will require equal amounts of matter and antimatter, his production method still is efficient enough to allow on-board manufacture of all the positrons necessary to power the engine.

I here point out that if some method can be found to use the output of a positron-electron reaction to heat a propellant, creating a

"dilute" rather than a "pure" antimatter system, that the production of sufficient antimatter to operate the engine becomes even less of a problem.

Unfortunately, neither of the two papers addresses this particular permutation of antimatter rockets. Cassenti does not address propellant heating by gamma radiation alone, and Wickman does not address propellant heating at all. It may be that combining the two systems may result in an excellent propulsion system better than either one alone.

Incidentally, copies of these two papers may be acquired by writing to the American Institute of Aeronautics and Astronautics, 1290 Avenue of the Americas, New York, N.Y. 10104. You can refer to the papers by number: the Cassenti paper is AIAA-81-1531, and the Wickman paper is AIAA-81-1532.

The Joint Propulsion Conferences offer amazing new ideas in propulsion, and if readers are interested in the technical end of commercial spaceflight, they should keep a close eye on these events. The next one will be in Cleveland, Ohio in June of 1982. These conferences, along with conferences on many other subjects, are announced in the AIAA Bulletin, which is a part of the magazine Astronautics and Aeronautics. Listings of papers appear periodically in the same publication. Papers are \$3.00 each, \$2.00 for AIAA members.

A few other papers from the 17th Joint Propulsion Conference which I found intriguing (and which may be covered in later Reports) were:

Shuttle Propulsion Using Electromagnetic Force Fields by J.E. Cox (AIAA-81-1535)

Investigation of a Quantum Ramjet for Interstellar Flight by H.D. Froning, Jr. (AIAA-81-1533)

Anti-gravity with Present Technology: Implementation and Theoretical Foundation by F.E. Alzofon (AIAA-81-1608)

I point out that while some of these papers are very theoretical in nature, all of them are serious, and written by serious scientists.

OTRAG: One piece of news-- The OTRAG division remaining in Libya has decided to close down its Libyan operation. This was primarily to avoid political trouble with neighboring African nations. OTRAG still claims to want to launch commercial payloads, and is looking for other sites.

Until next time...

Sincerely,



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