Re: In Situ Propellant Production

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- *Date*: Tue, 10 Feb 2009 00:39:00 −0800 (PST)

Several more early reports:

Title: Feasibility of rocket propellant production on Mars
Author(s): Ash, R. L.; Dowler, W. L.; Varsi, G.
Abstract: In situ production of rocket propellant to reduce landed mass requirements for Mars return missions has been investigated. The analysis has shown that a system which utilizes atmospheric carbon dioxide and soil moisture to produce liquid methane−oxygen propellant requires a landed mass which is less than half the mass of the ascent vehicle it produces.
NASA Center: Jet Propulsion Laboratory
Publication Date: Sep 1, 1978
Publication Information: Acta Astronautica, 5, Sept, Number of Pages = 20

Title: Oxygen production for interplanetary return missions
Author(s): Richter, R.; Ash, R.; Dowler, W.
Abstract: Interplanetary missions with extraterrestrial returns are limited by large propulsion mass requirements. The injected mass landed on an extraterrestrial body can be reduced substantially by utilizing indigenous materials for the production of propellant on the extraterrestrial body. Analyses reported show that for Mars return missions, in situ production of oxygen during the wait between landing and the next low−energy return opportunity reduces the Earth−launch mass requirements to the allowable limit for direct entry and direct return missions. A small chemical processor using radioisotope thermal energy can extract oxygen several times its own mass from carbon dioxide, during the several−hundred−days wait on Mars. The fundamental element of the concept is the electrolytic process. Solid electrolyte cells for extracting oxygen from gaseous feedstock are identified. The basic physical principles underlying the extraction process are analyzed, and the relations between the major parameters established. The laboratory equipment for experimental investigation of the process is presented.
NASA Center: Jet Propulsion Laboratory
Publication Date: Mar 1, 1980
Publication Information: APL The 1980 JANNAF Propulsion Meeting, Vol. 5, p 281−299, Number of Pages = 19

Title: Outer planet satellite return missions using in situ propellant production
Author(s): Ash, R. L.; Cuda, V., Jr.; Stancati, M. L.; Niehoff, J. C.
Abstract: In situ production of oxygen and oxygen with hydrogen for utilization as return propellant from the Galilean satellites has been investigated. Europa has emerged as the preferred landing sight because of the availability of water ice and its surface temperature. When oxygen is used with methane transported from earth, a Europa sample return mission requires 4000 kg less estimated earth launch mass than a vehicle using space storable propellant. Neither methane nor oxygen require active refrigeration at Europa. When oxygen and hydrogen are both utilized to form the primary sample return propellant, the required processor mass increases, but the estimated earth launch mass requirement is reduced by an additional 550 kg.
NASA Center: NASA (non Center Specific)
Publication Date: Sep 1, 1980

Title: In Situ Propellant Production for improved sample return mission performance
Author(s): Stancati, M. L.; Niehoff, J. C.; Wells, W. C.; Feingold, H.; Ash, R. L.
Abstract: In Situ Propellant Production (ISPP) on the surface of a target body is evaluated as a potential way to relax sample return mass constraints and to improve mission performance. Utilization of an oxygen/methane bipropellant combination for primary outbound and return propulsion has a significant favorable impact upon Earth escape requirements. A small sample can be returned from Mars using a single Shuttle/IUS(Twin) launch. Performance and design data are presented for the Mars mission. For sample returns from selected Galilean satellites, launch requirements are reduced by fifteen to forty percent. An assessment is made of overall utility of ISPP to planetary missions.
NASA Center: Jet Propulsion Laboratory
Publication Date: JAN 1, 1980

Title: A review of in situ propellant production techniques for solar system exploration
Author(s): Hoffman, S. J.
Abstract: Representative studies done in the area of extraterrestrial chemical production as it applies to solar system exploration are presented. A description of the In Situ Propellant Production (ISPP) system is presented. Various propellant combinations and direct applications along with the previously mentioned benefits and liens are discussed. A series of mission scenarios is presented which is studied in the greatest detail. A general description of the method(s) of analysis used to study each mission is provided. Each section will be closed by an assessment of the performance advantage, if any, that can be provided by ISPP. A final section briefly summarizes those missions which, as a result of the studies completed thus far, should see a sizable benefit from the use of ISPP.

NASA Center: NASA (non Center Specific)
Publication Date: Apr 1, 1983

Title: Novel extraterrestrial processing for space propulsion
Author(s): Ramohalli, K.; Dowler, W.; French, J.; Ash, R.
Abstract: In the present quantitative consideration of space processing concepts for chemicals, theoretical parametric calculations are supplemented by a bench scale experiment. Attention is given to the case of water splitting to generate hydrogen and oxygen for a simple rocket motor that can be used in periodic thrusting. This concept of in situ propellant production is treated in detail and compared with more recent energy and materials technologies.
NASA Center: Jet Propulsion Laboratory
Publication Date: Oct 1, 1985
Report Number: IAF PAPER 85−166
Notes: IAF, International Astronautical Congress, 36th, Stockholm, Sweden, Oct. 7−12, 1985. 15 p.

Title: Presentation material for the Manned Mars Mission Study Group
Author(s): NONE
Abstract: This report contains preparation materials for the three Manned Mars Mission meetings in the winter and spring of 1985. Topics include the outline of the most conservative mission from which to base comparisons on, basic mission operations and design, and preliminary mission integration analysis for the Mars Exploration Program. The orbital mechanics of Mars and its moons are given with respect to Delta−Vs. Sensitivity studies with regard to payload mass, mission velocity, and propulsion system characteristics are given. Space vehicle configurations are represented. Preliminary results of In−Situ Propellant Production (ISPP) work are outlined. An analysis of options for recovery of mission module and crew in the earth orbit is presented. The Mars Excursion Module (MEM) is detailed. A design comparison for the Venus Swingby Mission is illustrated. Conclusions reached by the third meeting include the need for lunar produced hydrogen, the necessity of low costs for lunar launches, the benefit of Phobos produced O2, and the fact that L2 operations are slightly better than LLO.
NASA Center: NASA (non Center Specific)
Publication Date: Dec 1, 1985

Title: Mars sample return mission options (1996−2005)
Author(s): Sergeyevsky, A. B.; Devries, J. P.
Abstract: Missions to the surface of Mars, carrying a Rover and having a sample return capability, constitute another logical step in the exploration of that planet in the late 1990's. Results of a recent study are described. A comparison of viable mission options, involving: retropropulsion vs. aerobraking/aeromaneuvering, direct return vs. Mars orbit rendezous, as well as the future potential of 'in−situ propellant production', is presented. An overview of a variety of scenarios of unmanned expeditions to Mars and their

subsequent return to earth, within the addressed time period, is provided.
NASA Center: Jet Propulsion Laboratory
Publication Date: JAN 1, 1986
Report Number: AAS PAPER 85−417

Title: Chemical production on Mars using in situ propellant production technology
Author(s): Ash, Robert L.
Abstract: In situ propellant production (ISPP) was examined in terms of its applicability to a manned Mars mission. Production of oxygen from Martian atmosphere was used as the baseline system for ISPP technology assessment. It was concluded that production of oxygen was an important element in a manned Mars mission which could be developed in terrestrial laboratories. Expert system methodology will be required to enable reliable, autonomous production of oxygen. Furthermore, while no major technical breakthroughs are required, this research requires a long lead time to permit its systematic evolution.
NASA Center: NASA (non Center Specific)
Publication Date: May 1, 1986
Publication Information: NASA. Marshall Space Flight Center Manned Mars Missions. Working Group Papers, Volume 1, Section 1−4, p 377−385,

Title: Mass and power estimates for Mars in−situ propellant production systems
Author(s): Frisbee, R. H.
Abstract: An in−situ propellant production (ISPP) concept, a method for producing oxygen from carbon dioxide in the Martian atmosphere, is evaluated. The concept considered here employs zirconia membrane technology to separate O2 from CO2. Several options which can improve the reliability of the CO2/O2 ISPP system and also reduce the mass and power requirements are examined, and it is noted that the use of absorption pumps and advanced zirconia membranes significantly improves system reliability by eliminating the rotating turbomachinery of mechanical pumps. Mass and power requirements of ISPP systems designed to produce O2 only from CO2 (for an unmanned Mars mission) and to produce both CO and O2 from CO2 (for a manned Mars mission) are evaluated.
NASA Center: Jet Propulsion Laboratory
Publication Date: Jun 1, 1987
Report Number: AIAA PAPER 87−1900

Title: The ballistic Mars hopper − An alternative Mars mobility concept
Author(s): Sercel, Joel C.; Blandino, John J.; Wood, Kristin L.
Abstract: The ballistic Mars hopper is proposed as an alternative mobility concept for unmanned exploration of the Martian surface. In the concept, oxygen and carbon monoxide produced from the Martian atmosphere are used as propellants in a rocket propulsion system for an unmanned vehicle on suborbital trajectories between landing sites

separated by distances of up to 1000 km. This mobility concept is seen as uniquely capable of allowing both intensive and extensive exploration of the planet using only a single landed vehicle of mass approximately 2000 kg. The technical challenges associated with in−situ propellant production on the surface of Mars are reviewed. A rocket propulsion subsystem capable of using oxygen and carbon monoxide as propellants is described. Finally, results of mission analysis and a hopper landing hazard simulation are reported. It is concluded that an attractive Mars hopper can be developed based on relatively near−term technology.
NASA Center: Jet Propulsion Laboratory
Publication Date: Jun 1, 1987
Report Number: AIAA PAPER 87−1901

Title: A new look at oxygen production on Mars − In situ propellant production (ISPP)
Author(s): Frisbee, Robert H.; French, James R., Jr.; Lawton, Emil A.
Abstract: Consideration is given to the technique of producing oxygen on Mars from CO2 in the Martian atmosphere via in situ propellent production (ISPP). Mission implications of ISPP for both manned and unmanned Mars missions are described as well as ways to improve system reliability. Technology options that improve reliability and reduce power requirements include the use of adsorption pumps and advanced zirconia membranes. It is concluded that both manned and unmanned missions will benefit greatly from ISPP, especially in the context of a permanent manned base on Mars.
NASA Center: Jet Propulsion Laboratory
Publication Date: Jan 1, 1987
Report Number: AIAA PAPER 87−0236

Title: In−situ propellant advantages for fast transfer to Mars
Author(s): Galecki, Diane L.
Abstract: The advantages of in situ propellant for a fast transfer to Mars were studied as compared to all earth−based propellants and other options for reduction of total masss in low earth orbit. For a 10−year, 10−mission model and a baseline vehicle taken from the literature, the total reduction in number of earth launches was calculated. The scenario in which the return propellants are transferred to Mars on a slow cargo vehicle provides a 29−percent reduction in ALS launches over the baseline scenario in which all propellants are brought directly from earth. The scenarios in which in situ propellants are used for a successively greater portion of the total mission continue to reduce the number of launches required. With Mars propellant used for the Mars ascent vehicle and the return leg of the mission, a 59−percent reduction in launches is obtained. Finally, if the oxygen, or oxygen and fuel, for the outbound leg of the mission is also obtained by in situ production, from the moon for example, then the total reduction in number of earth launches is more than 80 percent.
NASA Center: Glenn Research Center
Publication Date: Jul 1, 1988

Report Number: AIAA PAPER 88−2901

Title: Oxygen plant breadboard design, and techniques for improving mission figure−of−merit
Author(s): Ramohalli, Kumar
Abstract: A breadboard oxygen plant to process anaerobic carbon dioxide is designed and constructed; the objective is not only to produce a key propellant component extraterrestrially, but also to develop the important technologies that are necessary for a successful operation of in−situ materials utilization hardware. The solid electrolytic cells are supplied to specifications by an established vendor. The cell thermal control, electrical control, and flow control are installed after detailed designs. Extensive data are obtained that characterize the operation of the plant as the input parameters are varied. The initial mass, energy, and volume−needs provide the input to a figure−of−merit software program to calculate the impact of various candidate technologies upon the overall mission. The desirability of studies on storage and high−density propellants is shown. This task dovetails into other tasks that are evaluating alternative cell materials, catalysis for compactness, and smart sensors for effective control.
NASA Center: NASA (non Center Specific)
Publication Date: Apr 1, 1991
Publication Information: NASA Space Engineering Research Center for Utilization of Local Planetary Resources, 8 p, Number of Pages = 8

Title: Options for Martian propellant production
Author(s): Dowler, Warren; French, James; Ramohalli, Kumar
Abstract: A quantitative evaluation methodology for utilizing in−situ resources on Mars for the production of useful substances. The emphasis is on the chemical processes. Various options considering different feedstock (mostly, carbon dioxide, water, and iron oxides) are carefully examined for the product mix and the energy needs. Oxygen, carbon monoxide, alcohols, and other chemicals are the end products. The chemical processes involve electrolysis, methanation, and variations. It is shown that maximizing the product utility is more important than the production of oxygen, methane, or alcohols. An important factor is the storage of the chemicals produced. The product utility is dependent, to some extent, upon the mission. A combination of the stability, the enthalpy of formation, and the mass fraction of the products is seen to yield a fairly good quantitative feel for the overall utility and maximum mission impact.
NASA Center: Jet Propulsion Laboratory
Publication Date: JAN 1, 1991
Publication Information: Arizona Univ., Resources of Near−Earth Space: Abstracts, p 28, Number of Pages = 1
Notes: In Arizona Univ., Resources of Near−Earth Space: Abstracts p 28 (SEE N91−26019 17−91)

Title: Assessment of potential benefits from lunar/Mars propellant production for support of human exploration of the moon and Mars
Author(s): Jacobs, Mark K.; Collins, John T.; Stancati, Michael L.
Abstract: This paper describes an assessment of potential benefits offered through use of lunar/Mars in situ propellant production to support manned missions to the moon and Mars. Resources available at each location and processing options for their extraction are discussed. Key infrastructure and support systems needed to sustain the propellant production operation and to deliver the propellants from their point of origin to the point of application are defined. The analysis focuses on reductions of earth launched mass over the course of multiple missions to assess the potential savings offered. Initial results show the impact of requirements for sustaining in situ propellant production systems on benefits offered during steady−state operation.
NASA Center: NASA (non Center Specific)
Publication Date: Oct 1, 1991
Report Number: IAF PAPER 91−658

Title: In situ propellant production: Alternatives for Mars exploration
Author(s): Stancati, Michael L.; Jacobs, Mark K.; Cole, Kevin J.; Collins, John T.
Abstract: Current planning for the Space Exploration Initiative (SEI) recognizes the need for extraterrestrial resources to sustain long−term human presence and to attain some degree of self−sufficiency. As a practical matter, reducing the need to carry large supplies of propellant from Earth will make space exploration more economical. For nearly every round trip planned with conventional propulsion, the actual payload is only a small fraction − perhaps 10−15 percent − of the mass launched from Earth. The objective of this study was to analyze the potential application for SEI missions of propellants made exclusively from lunar or martian resources. Using such propellants could minimize or eliminate the cost of carrying propellant for surface excursion vehicles and return transfers through two high−energy maneuvers: Earth launch and trans−Mars injection. Certain chemical mono− and bipropellants are candidates for this approach; they could be recovered entirely from in situ resources on the Moon and Mars, without requiring a continuing Earth−based resupply of propellant constituents (e.g., fuel to mix with a locally obtained oxidizer) and, perhaps, with minimal need to resupply consumables (e.g., reagents or catalyst for process reactions). A complete assessment of the performance potential of these propellants must include the requirements for installation, operations, maintenance, and resupply of the chemical processing facility.
NASA Center: NASA (non Center Specific)
Publication Date: Oct 1, 1991

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Mars Direct dates from 1991. But by this time, considerable work had

not only already been done on ISPP (In Situ Propellant Production), it had also been widely disseminated in the open technical press. Note how many of these reports were in fact AIAA papers, which are pretty much bread−and−butter of the aerospace technical information exchange.
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