Gary barnhard - Re: ACS parameters for Ed Belbruno - please check

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From: Ethan Chew <spacefelix@gmail.com>
To: Nastia Soukhareva <nastia.soukhareva@gmail.com>, Eric Shear <renegade.om...
Date: 2/6/2016 12:41 AM
Subject: Re: ACS parameters for Ed Belbruno - please check
Cc: Eric Dahlstrom <Eric.Dahlstrom@internationalspace.com>, Gary Barnhard <B...
Attachments: Trajectory Design for Alpha CubeSat.pdf; Belbruno Trajectory & Propulsion Capabilities Analysis.xlsx

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Alright,

Based off the attached Belbruno trajectory developed, I have determined the propulsion system capabilities in terms of total impulse and total runtime to be able to meet his trajectory's DeltaV requirements.

I've evaluated our baselined NOX-Aluminized Paraffin hybrid HTSD motor as well as our LTLD options from HYDROS, Phase 4 CAT Ambipolar and Busek BIT-1 using propellants that met Belbruno's minimum DeltaV of 180 m/s (per manufacturer's specsheets). Spreadsheet attached.

Conclusions:

- The reduced DeltaV of the Belbruno trajectory allows us to eliminate the combination HTSD-LTLD propulsion system and free up mass and volume for payloads.
- Some propulsion systems have an overly long propulsion runtime (on the order of months to days) to impart the required impulse for the required DeltaV. Belbruno has recommended that propulsive phases be kept to a few minutes per phase.
    - This leaves us with a NOX-Aluminized Paraffin Hybrid HTSD motor or a HYDROS as our best options for propulsion.
- Propellant mass and volume are no longer limiting factors on the mission due to the reduced DeltaV. There is room to add additional propellant and open up further destinations for the ACS mission.

I am going to take the next hour to develop this into a report. Nastia, my apologies for the long time. I will do my best to get this to you shortly.

- Ethan

On Fri, Feb 5, 2016 at 2:06 PM, Ethan Chew <spacefelix@gmail.com> wrote:

> Comments acknowledged and in-work.
>
> Will develop the total impulse calculations for CAT Ambipolar.
>
> Also will add:
>
> - HTSD Propulsion System Engine Chamber and Nozzle design calculations and method.

- Development of combination HTSD & LTLD propulsion system volumes and masses based on updated trajectory DeltaVs and planning (reference to loads for structural system).

Expect delivery by 6pm CST today 2/5/16.

On Fri, Feb 5, 2016 at 7:50 AM, m d <2mdoty@gmail.com> wrote:

> My edits and comments are in green
>
> On 2/5/2016 3:49 AM, Ethan Chew wrote:
>
> > Hello,
> >
> > Attached is the latest draft of the ACS Propulsion Report. It is pending the determination of the mathematical and physics-based relationships between Thrust & I_sp and combustion chamber and nozzle characteristics for HTSD and power and propellant atomic mass for LTLD. Otherwise, we can put them as pending/on-going analyses for engineering. Aaron, if you may assist on this, it would be appreciated.
> >
> > Eric S. and Mike, please continue to provide information in the format within regarding HYDROS and CAT Ambipolar.
> >
> > Trajectories team (Eric D. and Gary), please advise on the orange highlighted sections within.
> >
> > Nastia, please use this report to support your propulsive structural loads design report.
> >
> > - Ethan
> >
> > On Fri, Feb 5, 2016 at 5:15 AM, Ethan Chew <spacefelix@gmail.com <mailto:spacefelix@gmail.com>> wrote:
> >
> > Acknowledged and thank-you.
> >
> > For LTLD propulsion, please use propellants that provide a minimum I_sp of 1,000s. Per the GT-1 Trajectory and DeltaV Analysis, this is the minimum I_sp to achieve the LTLD DeltaV required by the ACS deep space and lunar missions with a limited mass (1kg) and/or volume (1U) of LTLD propellant.
> >
> > Also, please analyze for Iodine even if the I_sp does not meet the 1,000s minimum as the high density of solid iodine may allow the propulsion system to store sufficient mass in the 1U volume limit.
> >
> > - Ethan
> >
> > On Fri, Feb 5, 2016 at 5:04 AM, m d <2mdoty@gmail.com <mailto:2mdoty@gmail.com>> wrote:
> >
> > Attached is data sheet for Cat Ambipolar. The table is for 1 Kg dry mass 3U spacecraft with 50 watts power. We would adjust these numbers for 90 watts power and use 14 Kg total

mass with propellant. our maximum propellant capacity will be 14 Kg - our total dry mass, which I am working on.

On 2/3/2016 9:41 PM, Ethan Chew wrote:

By far tonight, here is the template draft of the GT-2-level Propulsion System Report Outline. Propulsion Team, please respond to request below. Trajectories team, please advise per the below.

Sections of Note:

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Evaluation of candidate HTSD and LTLD propulsion systems against baseline propulsion requirements.

TO PROPULSION TEAM: Eric Shear and Mike Doty, please contribute the parameters for the HYDROS and CAT Ambipolar propulsion systems (as well as others) as follows:

* Classification and HTSD or LTLD
o HTSD: Isp < 500s
o LTLD: Isp > 1,000s
o If system has a dual operating mode between HTSD and LTLD, please state 'Dual' and state specifications for both modes.
* I_sp (s)
* Propellants and Propellant Densities (kg/m^3).
* Thrust (N)
* Total Impulse Imparted (N-s)
* Maximum Runtime (seconds)
* Propellant Safety (Compatible with NASA Cabin Safety Standards, Y/N?)
* If applicable, maximum propellant carriage volume (m^3).
* If applicable, maximum propellant storage lifetime (days).
* If applicable, DeltaV (m/s or else it can be calculated from the I_sp).

Trajectory Basis For Propulsion System Requirements
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TO TRAJECTORIES TEAM: Eric D and Gary, may you assist in verifying my statements in the report in regards to trajectory, the design and methods of its optimization are correct? I have highlighted within several areas of concern and need for information. Also, if you may provide an expected amount of trajectories DeltaV savings using the optimization methods of Belbruno and more, that would also be appreciated.

Thank-you.

- Ethan

On Wed, Feb 3, 2016 at 3:45 PM, Eric Dahlstrom <Eric.Dahlstrom@internationalspace.com
<mailto:Eric.Dahlstrom@internationalspace.com>
<mailto:Eric.Dahlstrom@internationalspace.com

<mailto:Eric.Dahlstrom@internationalspace.com>>> wrote:

Gary (& Ethan, Rich, and Mike),
Please check this information for Ed Belbruno. After we confirm the values, we can send it to him so he can begin his calculations. We need to get him information today.
- Eric

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Alpha Cubesat (ACS) Information for Ed Belbruno

Scenario:
ISS LEO -> Earth escape (C3≳0, >45000 km) [provided by launch provider]
Earth escape -> 4 million km
4 million km -> EML2 halo [note that the halo orbit is not a requirement, but was identified as a staging point]
EML2 halo -> elliptical Lunar orbit (hp>300 km, ra<10000 km)

Delta-v budget: 1500 m/s [after delivery to Earth escape]

Length of mission: 1 year

Spacecraft wet mass: 14 kg
Form factor: 6U cubesat

Ion propulsion:
4 x Busek BIT-1 thrusters (4 x 100 microN = 0.4 mN)
Isp = 2150 s

'burn for a day' delta-v: 86400 s -> 2.5 m/s

BIT-1 Ion Thruster datasheet
http://www.busek.com/index_htm_files/70011950%20RevA%20Data%20Sheet%20for%20BIT-1%20Ion%20Thruster.pdf

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V/r Ethan Chew

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to connect on Linkedin,
http://www.linkedin.com/inviteFromProfile?
from=profile&key=15253674&firstName=Mike&lastName=Doty

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V/r Ethan Chew

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> --
> to connect on Linkedin,
> http://www.linkedin.com/inviteFromProfile?
> from=profile&key=15253674&firstName=Mike&lastName=Doty

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