

**MASSACHUSETTS INSTITUTE OF TECHNOLOGY**  
**Department of Aeronautics and Astronautics**

**Field Exam in Space Propulsion**  
**January – 2014**

- There are two problems in this exam
- Read carefully each problem before writing your solution
- Make sure to state and be consistent with your assumptions
- Identify clearly your line of thought in your solutions
- Manage your time with care

### **Problem #1**

Consider the design of a spacecraft initially in an earth-like heliocentric circular orbit (radius =  $r_0$ , mass =  $m_0$ ). This spacecraft would feature an electric propulsion system, which is used to spiral-climb through pure angular thrust until reaching the orbit of Jupiter (radius =  $r_j$ ) in a fixed time  $t_m$ . There are two options for powering the spacecraft: nuclear and solar.

1. (80%) Assume the propulsion system operates with constant efficiency  $\eta$ , but not constant thrust. What are the optimal acceleration profiles in both cases? When minimizing  $\int d(1/m)$ , there is a constraint, and it might be helpful for its identification to look at the variation of orbital parameters in this “non-Keplerian” but near-circular trajectory.
2. (20%) Explain how one could calculate the maximum payload mass fraction ( $m_{\text{pay}}/m_0$ ).

**Problem #2**

What axial force is transmitted by the structure across section  $aa$  through the throat of a rocket? Explain how it could be calculated.

Can the same method, with appropriate modifications, be used for section  $bb$ ? For section  $cc$ ?

