Overview of the System Accommodation and Mission Design for a Fission Powered TSSM. R. L. Cataldo[1], S. R. Oleson[1], Y. H. Lee[2], [1]NASA Glenn Research Center, 21000 Brookpark Rd, Cleveland, OH 44135, [2]Jet Propulsion Laboratory, 4800 Oak Grove Dr, Pasadena, CA 91009

Introduction: In 2008, NASA's Jet Propulsion Laboratory (JPL) developed a conceptual design for a mission that would explore the Saturn's moon Titan using an orbiter, a Montgolfier balloon, and a lander. Powered by five Advanced Stirling Radioisotope Generator (ASRG) systems, the orbiter would carry over 100 kg of science instruments and 800 kg of Montgolfier/lander payloads to the Saturn system in seven years. Maneuvering the Titan Saturn System Mission (TSSM) [1] vehicle to get to Titan's orbit utilized three different propulsive techniques: a solar electric propulsion stage (SEP) with Earth and Venus flybys to 'pump-up' the orbit to reach Saturn (which is jettisoned after the last Earth flyby), a bipropellant chemical system used to capture and maneuver around the Saturn gravity well, and an aerocapture campaign which would greatly reduce the chemical propellant mass needed for Titan capture, and would provide additional atmospheric science.

The task given to the COMPASS team as part of the 2014 NASA Nuclear Power Assessment Study (NPAS) was to replace the proposed ~500 W ASRG systems with a notional 1 kW nuclear reactor, using either Stirling (Case 1) or thermoelectric (Case 2) power conversion systems. The ground rules stated that the reactor could not be used to power electric propulsion (in order to show how reactor power without electric propulsion could be implemented), a fixed boom should be used (to avoid the risk of deployable booms), and the baseline launch vehicle should be the Atlas 551 (consistent with the baseline TSSM concept), in order to minimize nuclear launch costs and make it comparable to the baseline TSSM.

	Units	Case 2 (Stirling FPS)	Case 3 (TE FPS)
Launch mass	kg	8415	9602
Initial C3	km^2/s^2	-15.3	-22.0
Initial Altitude of Apogee	km	39,171	23,301
Date, Beginning Of Spiral Out		3/14/18	5/4/17
Date, Earth Escape		7/3/20	6/7/20
Spiral Out Delta-V	m/s	3638	4328
Thruster Burn Time	Years	1.9	2.6
Total Spiral Out Duration	Years	2.3	3.1

Table 1. Key mission concept characteristics

The final conceptual designs developed [2] by the COMPASS team remained on the Atlas 551, kept a fixed boom, and still used the SEP stage, chemical propulsion and aerobraking. Table 1 summarizes the top-level details of each subsystem that were incorporated into the conceptual design. The SEP stage was key in keeping the TSSM Fission Power System (TSSM-FPS) spacecraft on the Atlas 551, as the additional mass of the fission system over the baseline ASRGs (~300 kg) and the propellant to push it required the vehicle to start in a near-geostationary transfer orbit (GTO) then spiral out to escape. The SEP stage would also provide the orbiter system with ~500 W of power through the spiral out and Earth flybys, so that the reactor need not be started until after the last Earth flyby, thus reducing the risk of an active reactor flying by the Earth, as well as reducing the required lifetime and radiation shielding from the reactor. This also reduced the required reactor shield mass. The vehicle (shown in Figure 1) shows the TSSM-FPS orbiter/reactor configuration post SEP separation.

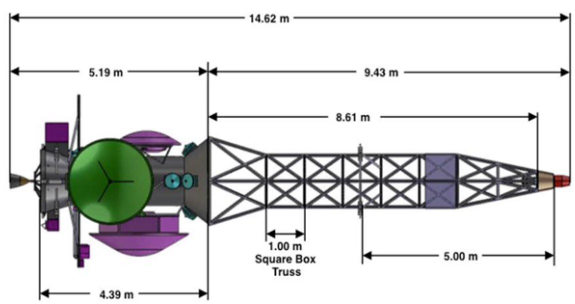

Figure 1. TSSM Orbiter concept with a 1.0 kWe Fission Power System

A 4.5-meter aerobraking plate was added to maintain the two-month aerobraking campaign that the TSSM baseline vehicle performed with a forward mounted large 4-meter diameter antenna dish used in the baseline concept but was removed for this study to mount the reactor/boom assembly in its place. The ~ 8-meter boom and radiation shield thickness supports a 25 krad dose at the spacecraft electronics and instruments over a 15-year mission. The rector shield however did have to be increased on one side to avoid back-scattering of neutrons off of the smaller, now side mounted antenna back onto the spacecraft.

With the addition of the reactor and starting in GTO the vehicle would takes an additional 2 to 3 years to get to Titan but the additional power allows the planned science instrument suite to be run concurrently, thus almost doubling the returned science data (up to 9 Gb). For follow-on studies it is recommended that the notional reactor power be increased (~10 kW) and nuclear electric propulsion replace the SEP stage, reducing the chemical propellant and eliminating the aerobraking campaign to simplify the vehicle. Alternatively, one might be able to keep the 1 kW reactor and eliminate the SEP stage by using a larger launch vehicle (Delta IV heavy, Falcon heavy, or Space Launch System (SLS)).

References:

[1] *Titan Saturn System Mission Study Final Report," NASA Task Order #NMOO710851, January 30, 2009*

[2] *COMPASS Final Report: Titan Saturn System Mission (TSSM), CD-2014-109*