1. **Techport.** https://techport.nasa.gov. <PDT INPUTS IN RED> NASA TechPort is a web-based software which provides the NASA community with a single, integrated, comprehensive resource for locating information about NASA-funded technologies. Users can find a variety of information about technologies, such as descriptions, images, funding organization(s), locations where work is being performed, and associated technology areas (aligned to the Technology Roadmaps).
   Please confirm the following information is correctly captured for your project:

   a. Project Name <Propulsive Descent Technologies (PDT)>
   b. Project Start and Stop Dates <Start 9/2013, end 10/2015>
   c. Project Start and Stop TRL <Start = 3 Stop = 6>
   d. Current TRL (as of FY14) < = 3>
   e. Primary Space Technology Roadmap – <Technology Area TA 09.2.3 Supersonic Retropropulsion>
   f. Brief Description of Project (short sentence and a more detail description)

The PDT project will investigate the use of retro propulsion during the supersonic phase of atmospheric entry for Mars missions. The project technical approach involves a combination of procurement and evaluation of commercially provided flight data, development of candidate vehicle configurations, and engineering calibration of computational fluid dynamics models to the available flight data.

   g. Technology Classification (Hardware or Software)
      i. If Hardware (select one):
         Architecture
         System
         Subsystem
         Assembly
         Component or Part
         Material
      ii. If Hardware (select one):
         Business Administration Hardware
         Transportation Hardware
         Unmanned Flight Hardware
         Unmanned Spaceflight Hardware
         Wearable – Individual Hardware
         Other Object or Thing
         Computer Hardware
         Construction Hardware
         Facility Building or Infrastructure
         Ground Scientific Research or Analysis
         Ground Support & Mission Operations
         Manned Flight Hardware
         Manned Spaceflight Hardware
         Tools
      iii. If Software (select one):
         Compiler
         Complex Electronics Software
         Firmware
         Language
         Macro
         Memory
         Operating System
      iv. If Software (select one):
         Business Administration Software
         Transportation Software
         Unmanned Flight Software
         Unmanned Spaceflight Software
         Wearable – Individual Software
         Other Software
         Facility Building or Infrastructure
         Ground Scientific Research or Analysis
         Ground Support or Mission Operations
         Manned Flight Software
         Manned Spaceflight Software
         Security Software

Eng, Design, Modeling, or Analysis *Tools Software*

h. Description of Technology

Future missions to Mars require landed mass that exceeds the capability of current entry, descent, and landing technology. New technology and techniques are required to increase atmospheric entry and landing capabilities for high mass items. This capability is needed in order to enable future human-precursor and human-scale missions to Mars.

One possible technology to enable future high mass missions to Mars is the use of retro propulsion during the entry phase. Supersonic retro propulsion involves using thrusters directed in opposition to the oncoming airflow to decelerate the entry vehicle while it is traveling at supersonic speeds.

The project will seek to partner with a commercial launch provider to obtain flight data. The data acquired by the proposed government-commercial partnership are expected to include the following aerosciences products:

- Vehicle state (position, velocity, attitude, attitude rates, etc.)
- Temperatures, heating rates, and pressures on the vehicle's outer skin
- Imagery provided by NASA and its contractors, in addition to vehicle propulsion system performance data.

Available NASA Computational Fluid Dynamics (CFD) tools will be exercised at a few select conditions during the SRP burn for each flight data set in order to provide insight into how the models compare against the data. The commercial partner's engines will be properly scaled in the CFD calculations using established scaling parameters with varying degrees of exhaust modeling fidelity. Solutions will be completed on custom grids for each CFD code using geometries provided by the commercial partner.

Objectives (for each code):

1. Establish computational requirements (grid, run time, number of CPUs, etc.) and the effects of turbulence modeling and time-accurate simulations on results
2. Examine varying levels of engine exhaust modeling (perfect gas vs. simulated gas vs. multi-specie gas)
3. Provide best practices for obtaining grid-converged solutions (flow initialization, time step requirements, grid adaptation, etc.)
4. Make blind comparisons of the "best" solutions with the flight data set(s), including flight imagery provided by NASA

The PDT project will also develop vehicle configurations that support landing of a 2 metric ton (t) article on the Mars surface. Project representatives will develop trajectories and supersonic retro propulsion profiles for the vehicle configurations using the CFD models. The project will investigate interactions between vehicle subsystems, structures and thermal protection, the Mars aero environment, mass and center of gravity, and control techniques.

i. Capabilities provided by this technology

Advances in Propulsive Descent Technology will increase NASA's ability to safely land resources on the Mars surface. Refined computational fluid dynamics models will contribute to the definition of vehicle shapes and propulsion systems for Mars entry, descent, and landing applications.

j. Potential applications for this technology

Potential applications include entry, descent, and landing of any high mass item at an interplanetary destination with an atmosphere. Examples include large rovers, scientific instruments, in-situ resource utilization equipment, human precursor equipment, and vehicles and habitats for manned missions.

k. Benefits to NASA Funded Missions

Refinement of NASA computational fluid dynamics tools will benefit a wide range of NASA missions that involve vehicle dynamics in the supersonic regime. Contractor provided data from proof of concept flight testing of supersonic retro propulsion will contribute to the development of viable concepts for entry, descent, and landing of high mass NASA interplanetary missions.

l. NASA Lead Center or Facility and supporting centers

Lead: Texas, Johnson Space Center

m. U.S. States with Work

Participating Centers:
Texas, Johnson Space Center
California, Ames Research Center
California, Jet Propulsion Laboratory
California, Aerospace Corp
Maryland, Johns Hopkins University – Applied Physics Labs
Virginia, Langley Research Center
Alabama, Marshall Space Flight Center
Georgia, Georgia Tech University

n. Funding/Resources (list the organizations involved)
    i. NASA Mission Directorates or Offices Providing Funding/Resources:

Space Technology Mission Directorate

Game Changing Development Program

ii. NASA Centers and Facilities Providing Funding/Resources:

n/a

iii. Other U.S. Government Agencies Providing Funding/Resources:

(Navy is not contributing resources, we are funding them.)

iv. U.S. External Partners (Academia or Commercial) Providing Funding/Resources:

Georgia Tech University: NASA is partnering with the Georgia Tech Space Systems Design lab for development and analysis of conceptual Mars re-entry vehicles that utilize supersonic retro propulsion.

v. International Partners Providing Funding/Resources: <not applicable>

o. Internal and External Infusion Status

The PDT project team includes technical experts from civil service, contractor launch providers, and academia.

The external infusion of data from recent innovative full scale contractor flight testing of retro propulsion is a key element of the PDT project.

The project expects to publish results of the effort in open literature within the constraints defined by contractor proprietary data considerations and the International Traffic in Arms Regulations Act.

p. NASA Strategic Goals

The PDT project aligns with the NASA 2014 Strategic Plan Objective 1.1: Expand human presence into the solar system and to the surface of Mars to advance exploration, science, innovation, benefits to humanity, and international collaboration.

Concept Sketch of a Mars Vehicle performing a retro propulsion burn during atmospheric entry