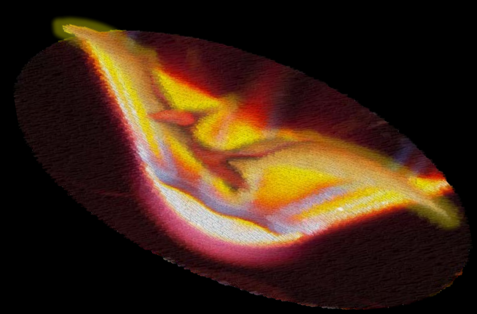
Pterodactyl: Integrated Control Design for Precision Targeting of Deployable Entry Vehicles



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Attention Scientists!

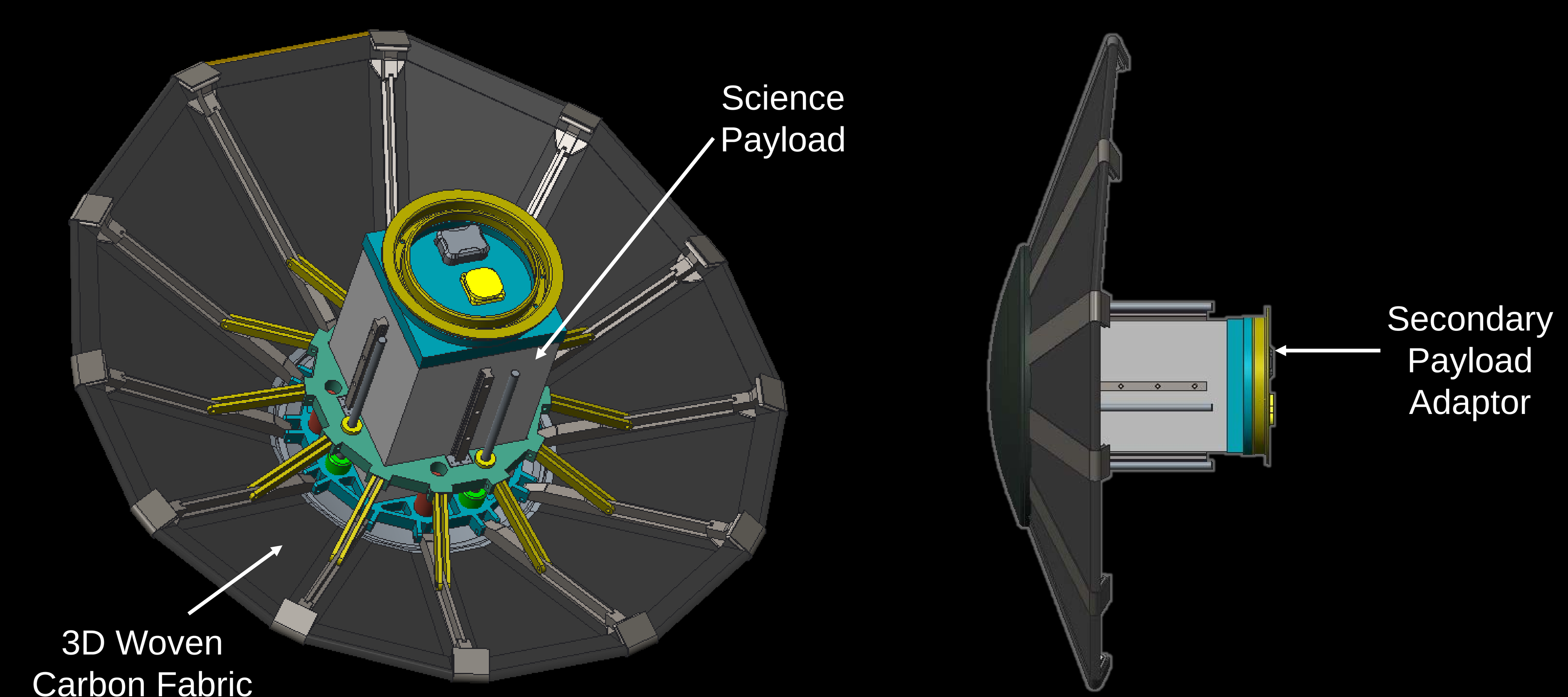
Why limit yourself to remote sensing when you can explore *in situ* or return samples to Earth? We are developing a deployable atmospheric entry system for secondary payloads with the capability of autonomous precision landing. Interested in more details? Read below, and contact me with your questions.

Abstract;
Deployable Entry Vehicles (DEVs) enable in situ scientific exploration at destinations with atmospheres across the solar system. Because they stow in a compact form and deploy only when ready to enter the atmosphere, DEVs relax the volume constraint imposed by rigid aeroshells. This work seeks to do for a DEV what the Wright Brothers did to propel modern day aviation: develop the guidance and control (G&C) methods that will make maneuvering and precision landing of DEV a reality. The Pterodactyl project objective is to deliver an integrated G&C methodology for a DEV, based on a detailed analysis that utilizes a Multi-disciplinary, Design, Analysis and Optimization (MDAO) framework.

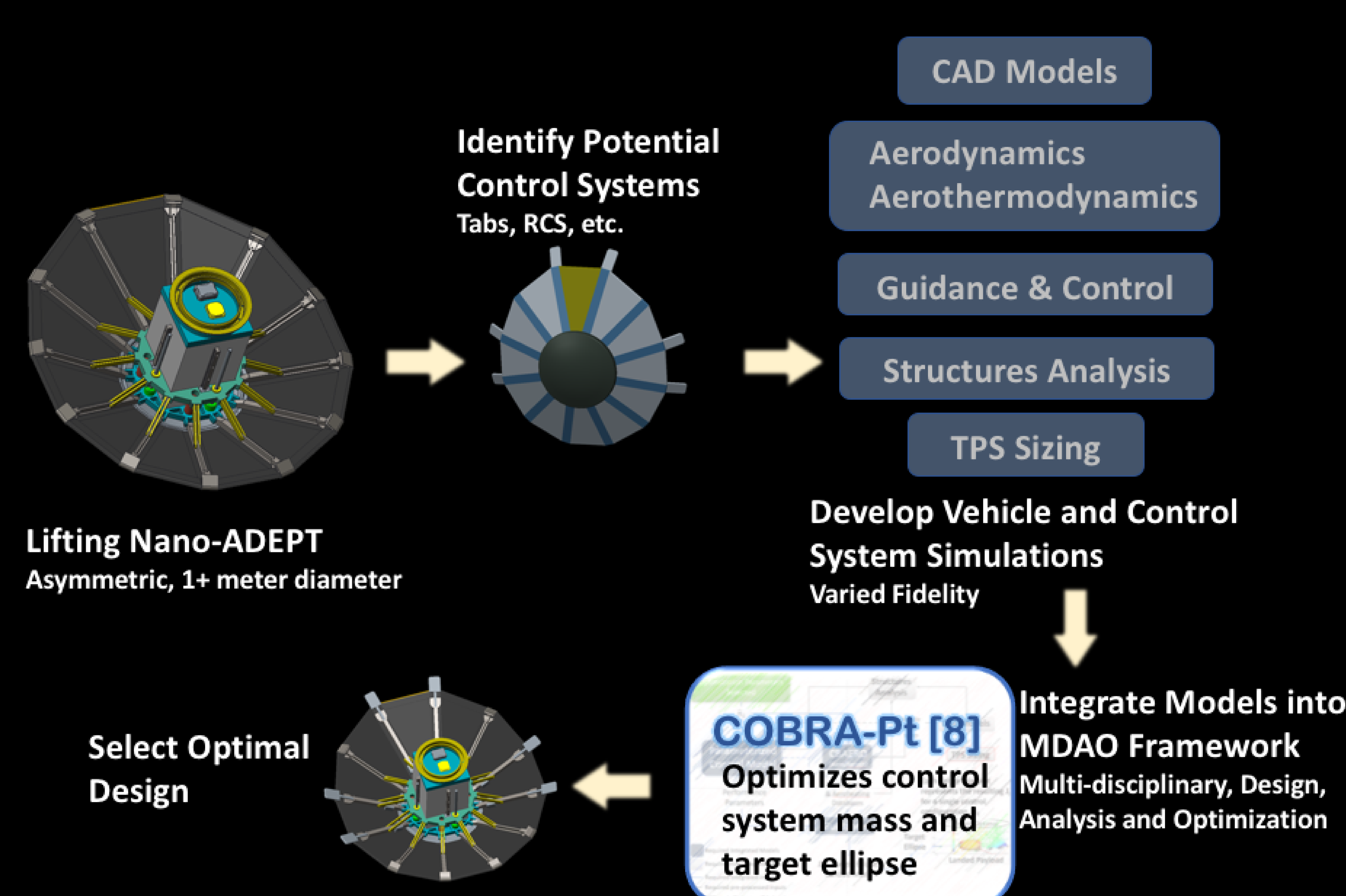
The current state-of-the-art for blunt body entry G&C is rooted in the precision landing of vehicles such as Mars Science Laboratory (MSL) and Apollo, which used a propulsive reaction control system (RCS) to steer [1]. Recent research has taken a particular interest in non-propulsive control for DEVs, including direct force control [2]–[4] (angle of attack modulation via control surfaces or mass movement) and drag modulation [5], [6] (discrete change in ballistic coefficient). Using the MDAO framework that includes a guidance and control model to explore multiple control concepts for a DEV will shed light on the best design approach for these vehicles. In Pterodactyl, we will complete this study for a novel DEV concept, and then we will fabricate a functional prototype to help validate the design. The project is expected to down-select to a final control architecture by the end of 2018, and complete fabrication of the prototype by the end of 2019.

The DEV chosen for detailed study in this project is the Adaptable Deployable Entry and Placement Technology (ADEPT). ADEPT uses a revolutionary 3D-woven carbon fabric that is foldable, can serve as primary structure, and can survive the extreme heating environment of atmospheric entry. The specific configuration of ADEPT under investigation is called Lifting Nano-ADEPT (LNA) [7]. LNA is designed for secondary payloads missions that require precision landing either for scientific objectives at a target destination or for payload recovery at Earth.

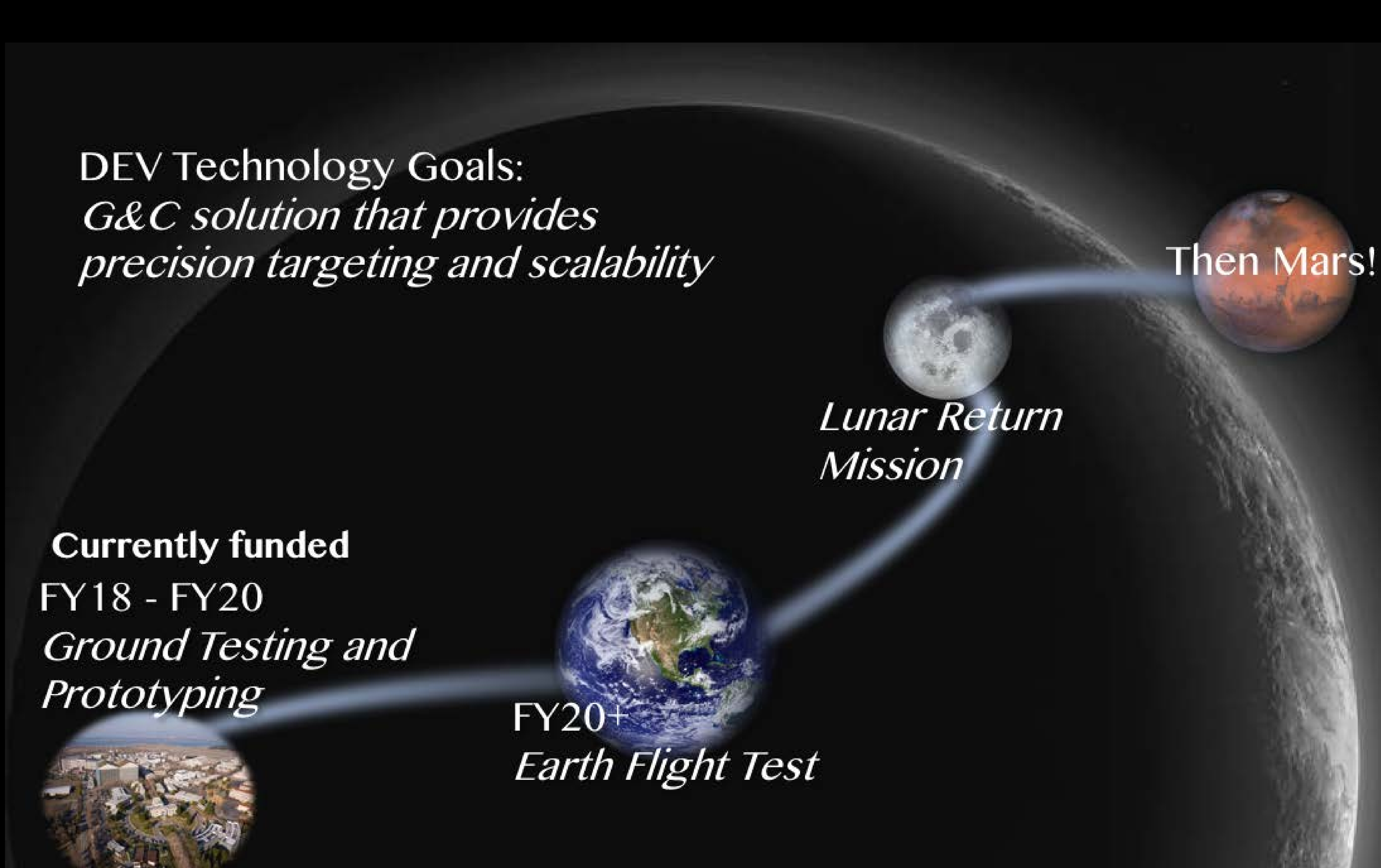
The MDAO framework being created through this research, called COBRA-Pt [8], will combine three critical elements of the system design: a guidance algorithm with Monte Carlo, a parametric control model, and vehicle geometry details. Novel control models being studied are deployable aerodynamic surfaces as well as shape morphing. These concepts will be compared at the system level with a more traditional propulsive RCS by comparing several key performance parameters. Upon completion of the design study, a functional prototype of LNA will be fabricated that will include the integration of guidance software and relevant control actuators. We expect this study will provide critical data that could feed into the development of an Earth-based flight test of LNA. The COBRA-Pt framework will provide a modular system by which to study any DEV concept in any atmosphere.



Lifting Nano-ADEPT



Pterodactyl Design Process Overview



Development and Mission Timeline

References: [1] D'Souza S.N. and Sarigul-Klijn N. (2014) Progress in Aero. Sci., 68, 64-74. [2] Ciancolo A. M. et al. (2011) NASA/TM-2011-217055. [3] Cianciolo A. D. and Polsgrove T. T. (2016) AIAA Space 2016. [4] Korzun A. M. et al. (2013) 31st AIAA Applied Aero. Conf. [5] Putnam Z. R. and Braun R. D. (2014) JSR, 51, 128-138. [6] Saikia S.J. et al. As-tro. Specialist Conf. [7] Wercinski P. (2016) FY16 Center Innovation Fund LNA Final Report. [8] Garcia J. et al. (2010) 10th AIAA/ASME Joint Thermo. and Heat Transfer Conf.