**SEE REFERENCE LITERATURE**

# Functional Analysis

Introduction of functions that sys must perform

* ADS functions
* ACS functions
* GNC functions

Difference between probe and orbiter

* Probe is limited to EDL only
* Orbiter primarily for on-station life

# Requirements

* Summary of requirements from baseline
* Update TBDs here
* Indicate if new requirements are added/ discovered
  + Maneuver rates
  + Slew maneuvers

# Calculations and model

**Functional results**:

* Note: Actions based on heritage (MSL/ phoenix for entry, MRO for orbiter)
* GNC process [Elements…]
  + sense data with IMU,
  + create estimation
  + transmit to earth
  + receive ephemeris data
* ACS process
  + Use stored momentum to passively counter torques
  + Use additional momentum for maneuvers
  + Periodic momentum desaturation
  + Thrusters for high-rate maneuvers/ desaturation

**Design process/results**:

* Process
  + Name key steps of this design phase (discussed later)
    - Requirements (described in previous section)
      * Control modes result
    - ACS Type
    - Disturbance Torques
      * Parametric python model
    - Hardware Selection
      * Parametric python model
    - Budgets
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  + Steps for later design phases
    - Control logic
    - Refined inputs
* ACS Type (3-axis stable, RWs)
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  + See design log
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  + Summarize results
* Disturbance Torques:
  + Include main equations
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  + Cyclic vs Secular
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    - IMU
    - Sensors
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* Budget summary
  + Final results
* Model Limitations:
  + LOD that of SMAD/ Elements (first order sizing)
  + Limited knowledge of required maneuvers and s/c geometry
  + Based on worst-case scenarios

# Risk

Consequences:

* Power loss
* Communication failure
* Mission failure

Mitigation:

* Based on heritage standard practices
* Critical components at least once redundant
* All critical maneuvers can be performed with both reaction wheels and thrusters
* Reaction wheels greater than minimum to use off-the-shelf components
* Flight proven hardware:
  + MIMU
  + RW
  + Star Trackers
* Sizing based on worst-case conditions

# V&V

* All functions verified independently
* Validated with FireSat mission design described in SMAD
  + Different input parameters
  + Output identical

# Compliance matrix

Table of requirements that are met

# Recommendations

Refinement of model:

* Better geometry data when available
* Larger hardware selection
* More specific requirements
  + Sensor accuracy -- > better sensor selection
  + Jitter + Settling Time -> exact thruster design
* Control Law definition

BODY TEXT

The Attitude and Orbit Control System (AOCS) consists of two primary sub-systems. The Attitude Control System (ACS) ensures that the spacecraft remains oriented in the proper direction, as defined by mission and sub-system requirements. The Orbital Control System (OCS) is responsible for determining the spacecraft's position and controlling manoeuvres to change its orbit. These changes may originate from station-keeping requirements or mission objectives. \cite{techreport:midterm2020} The following design is a first-order sizing of the most critical AOCS components. The mass, power and volume estimates driven by the specific hardware selection contribute to the overall design of the spacecraft.

# Functional Analysis

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Difference between probe and orbiter

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The MarsReveal mission has two applications of the AOCS: aboard the orbiter and on each of the probes. For each probes it is responsible for pointing during the de-orbit burn, and to maintain proper attitude during the entry, descent and landing phases. The control method here of is determined using heritage and trajectory requirements. Concerning the orbiter, the AOCS is responsible for keeping a specified pointing direction throughout all phases of the mission. During the nominal operation of the orbiter, when in a circular orbit around mars, one face containing the UHF antenna must always be nadir pointing. Any disturbing torques on the orbiter must therefore be accounted for to prevent pointing deviations.

The overall sizing of the Attitude Control System (ACS) is done on basis of the maximum disturbance torques it must counteract, and the total momentum it must be able to handle throughout. The disturbance torques can be categorised into cyclic and secular, where the former results in …

The AOCS is a closely integrated system that must autonomously monitor the spacecraft and perform corrective manoeuvres where necessary. The attitude determination system consists primarily of sensors that generate an estimate of the spacecraft’s attitude and position. The attitude control system (ACS) is designed to handle the torques and momentum acting on the spacecraft throughout its operational phase. For the orbiter this is calculated per orbit, while for the probe it mainly concerns the torques caused by the aerodynamics during re-entry. Each of these sensors has imperfections resulting in overall inaccuracies. To account for this, as well as

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In addition to the requirements identified in the baseline report, additional requirements were necessary in order to complete a first-order sizing. These are summarized in table xxx. Requirements such as manoeuvre rates, other pointing direction, or pointing accuracy are driving requirements in sizing the performance of the ACS. Additionally, for some requirements from the baseline report where values were initially unknown, have been updated here. Not all requirements from the baseline report are addressed here, as some will only have significance in more detailed design phases. These are not included in this table.

The requirements are divided into three categories: pointing direction, pointing accuracy, and manoeuver requirements. These requirements were collected from each of the spacecraft’s other subsystems to identify which would be critical to the design, as described in table xxx. (include table of only the driving requirements)

# Calculations and model

The AOCS design process consisted of six distinct steps: requirements determination, ACS type, quantification of disturbance torques, hardware selection, budget updates, and finally control logic selection. A python numerical model was created to generate a rough estimation of the spacecraft geometry, and to size and select specific actuator hardware to meet the functional requirements. The sizing is based on worst-case conditions, to ensure that the requirements will always be met.

\subsection\*{ACS Type Selection}

The AOCS sizing process for the orbiter is based primarily on its nominal mission phase, where it would function as a communications relay in a circular Martian orbit. The orbiter would not be subjected to large slewing requirements, but would need to maintain a reliable nadir pointing throughout the orbit. Due to pointing accuracy requirements along each of its axes, a 3-axis stabilised system is selected for the orbiter. This design choice is reinforced by performance tables found in SMAD, as well as previous similar missions such as the Mars Reconnaissance Orbiter (MRO). The lack of slewing requirements allows the system to utilize momentum wheels for primary attitude control. Attitude control thrusters are also included for possible exceptional high-rate slewing manoeuvres, and for periodic momentum wheel desaturation. Additionally, in case

For the probe, the AOCS is only active during the EDL phase. It must perform accurate pointing for the de-orbit burn, and attitude control during the atmospheric entry. Needing less pointing accuracy than the orbiter, and experiencing greater disturbance torques, the probe will rely on cold-gas thrusters for attitude control. For the de-orbit burn, it will utilize spin-stabilisation to rotate the entire probe about its roll axis, effectively fixing the angular momentum vector in inertial space \cite{SMAD}. This removes the need for vectored thrust control and minimizes the overall mass of the probe. The overall disk shape of the probe further ensures that the roll axis will have the greatest moment of inertia, guaranteeing stability. The aeroshell is designed such that it will be inherently stable throughout the hypersonic phase, and will need few corrective inputs from the attitude control thrusters. This is supported by the design of the Mars Science Lander, which required limited active control to remain within the specified deadbands \cite{2007\_Brugarolas}. Upon reaching the transonic phase, the ACS will become more active due the instability around Mach 1. Once the parachute is deployed, the remaining rotational inertia of the probe will be removed, changing the control type to 3-axis stabilized. This is necessary for the propelled descent as described in \chapter{EDL}

In sizing the AOCS, a fixed iterative process was used as described in SMAD. Before building a numerical model, the inputs and outputs of each sizing step were identified, to ensure that all requirements would be met.

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