8 Mission Analysis

8.1 General

Within the framework of mission integration, several important mission analyses are conducted to ensure that the mission objectives can be achieved (e.g. reliable spacecraft injection into the required orbit and in the correct attitude):

The analyses related to the flight plan and the environments are organised in two stages:

- A preliminary mission design analysis mainly concerned with the compatibility of the spacecraft design with the *Rockot* environment; the analysis ends up with the PDR (Preliminary Design Review)
- A final mission design analysis mainly concerned with the actual flight plan and the final flight predictions; the analysis ends up with the CDR (Critical Design Review).

EUROCKOT will perform the following analyses for each *Rockot* mission, as depicted in Figure 8-1:

- Trajectory and Mission Sequence
- Dynamics of Spacecraft Separation
- Dynamic Coupled Loads Analysis
- Electromagnetic Compatibility
- Thermal Environment
- Contamination Analysis (optional)

Other mission analyses, e.g. payload fairing venting analysis, payload fairing jettison clearance or spacecraft acoustic analysis, can be performed optionally if advisable because of special spacecraft characteristics.

8.2 Trajectory and Mission Sequence

In order to define the flight sequence, the Customer is requested to submit the following data:

- Payload orbital parameters
- Information about the elements of the payload which have to be jettisoned or deployed, including time and/or sequences of jettison or deployment

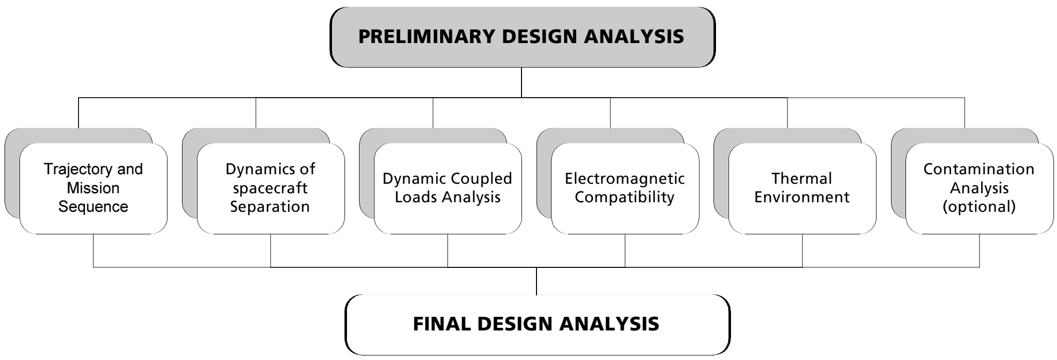

Figure 8-1: Mission Analysis Overview

- Orientation and stabilisation requirements for the payload during coast periods
- Requirements for injection accuracy and orientation of the payload prior to its deployment
- Required accuracy for orbital as well as for attitude parameters

The Customer has to consider restrictions imposed by the *Breeze* upper stage flight sequence. Orientation and stabilisation parameters must be agreed with the Customer.

The preliminary trajectory study establishes the feasibility of the required orbit and the associated performance margin. The resulting trajectory is then used as input data for various analyses such as orbit dispersion, loads, thermal, separation sequence and safety.

The final trajectory study defines:

- The ascent flight profile
- The actual launch vehicle data to be used (mass break-down, propulsion parameter adjustments), the actual launch vehicle payload data and the associated launch vehicle performance
- The flight event sequence for the on-board computer
- The guidance parameters for the on-board computer
- The position, velocity and attitude of the vehicle during the propulsive phase
- The orbit characteristics and injection accuracy prediction
- The ground track of the ascent trajectory
- The drop zones for stage 1, stage 2 and payload fairing
- The tracking and visibility zone evaluation

8.3 Dynamics of Spacecraft Separation

For implementation of the dynamics of spacecraft separation, the Customer has to submit the following:

- A description of the mechanical interfaces
- Spacecraft properties such as mass, center of gravity, moments of inertia and damping behaviour (e.g. fuel)
- Requirements for orientation of the payload after its deployment, as well as for possible spin requested after the payload separation
- Information on requested relative velocities of spacecraft after separation for constellation build-up

The preliminary flight mechanics study dynamics of spacecraft separation allows EUROCKOT to:

- Verify the feasibility of the required orientations of upper stage and spacecraft

- Define the necessary separation energy
- Verify the clearance at separation
- Determine the kinematic conditions after separation
- Issue a preliminary sequence of events
- Verify the orbital long-term clearance

In cases where a problem area is identified, corrective action must be agreed with the Customer.

The final dynamics of the spacecraft separation study repeats and confirms the studies performed during the preliminary analysis for the latest configuration data, taking into account the actual *Rockot* and payload parameters. Thus it enables EUROCKOT to:

- Define the data to be used by the on-board computer for the orbital phase (manoeuvres, sequence)
- Predict the clearance between the separated elements in orbital flight and verify collision avoidance including *Breeze* deorbit.

8.4 Dynamic Coupled Loads Analysis

The dynamic coupled loads analysis (CLA) includes several steps.

The preliminary dynamic coupled loads analysis (CLA) allows the first estimation of the in-flight loads applicable to the Customer's payload for lift-off, transonic flight, wind/gust, maximum dynamic pressure and separation events.

This study is based on the preliminary payload dynamic model submitted by the Customer according to the standard specified by EUROCKOT; see Section 8.4.1. The preliminary CLA includes the following items:

- Modal analysis for the composite launch vehicle / payload
- Description of the payload dynamic responses to the most severe longitudinal and lateral load cases induced by the launch vehicle
- Presentation of min./max. tables and time histories for forces, accelerations and relative deflections, as well as launch vehicle / payload interface, acceleration and force time histories at the nodes selected by the Customer
- Verification of the payload accommodation concept regarding interface loads as well as dynamic clearance between one or more spacecraft and the payload fairing during ascent

The dynamic coupled loads analysis allows the Customer to verify the validity of payload dimensioning and to adjust, if necessary, its qualification test plan after discussion with EUROCKOT.

The final coupled loads analysis enables EUROCKOT:

- To define the final prediction for in-flight loads
- To verify or adjust, if necessary, the Spacecraft Acceptance Test Plan, and associated notching procedure if applicable
- To verify that the *Rockot* payload does not affect the behaviour of the launch vehicle or its stability

8.4.1 Coupled Loads Analysis Scope

The coupled loads analysis is performed for the basic design cases of the orbit injection representing the most severe spacecraft load environment, namely:

- First stage ignition
- Wind + gust in the XOY plane of the LV
- Wind + gust in the XOZ plane of the LV
- First stage cut-off

Additional cases may be included in the CLA as agreed with a Customer, e.g.:

- Second stage ignition
- Second stage cut-off

Wind load direction for the "wind+gust" load case may be changed if agreed upon with the Customer.

8.4.2 Coupled Loads Analysis Report

The coupled loads analysis is performed in the Preliminary Design and Critical Design phases as well as in the event of any payload design modification (or design model updates) associated with changes in the payload dynamic properties. A CLA report is an integral part of the Preliminary/Critical Design activity.

A final CLA report is issued according to the agreement with the Customer. The report incorporates:

- Calculation method description
- Description of load cases and models used
- Tables of maximum and minimum values presented in different matrices
- Loading time domain data agreed upon with customers
- ASCII files of generalised accelerations and generalised displacements relative to the Craig-Bampton payload model for all the design cases

8.4.3 Requirements for Spacecraft Mathematical Model

The spacecraft mathematical model is to be provided by the Customer for a non-fixed structure mathematically reduced to a Craig-Bampton model format. In the case of a multiple satellite payload, the mathematical model will be provided to simulate the entire payload right-handed coordinate system coupled with the payload base geometric centre in the payload/adapter interface plane.

The model should incorporate:

- Coordinate system definition
- Interface node coordinates
- Numbers of the model's degrees of freedom (DOFs) and associated directions of displacements (rotations) in the LV coordinate system for each interface node; sequence of node DOFs; three displacements relative to the OX, OY and OZ axes and three rotations relative to the OX, OY and, OZ axes
- Stiffness, mass and damping matrices in a Craig-Bampton format
- Stiffness matrix verification results related to solid body displacements
- Transformation matrices and their line description if necessary. The standard for this is described in more detail in the EUROCKOT specification ESPE-0008.

Other formats of the mathematical model (for example a spring-mass model) are to be agreed with EUROCKOT. As far as physical displacement is concerned, the number of the model's dimensions must be equal to the total DOFs of the payload interface nodes.

8.5 Electromagnetic Compatibility Study

The preliminary electromagnetic compatibility (EMC) study allows EUROCKOT to check the compatibility between frequencies (and their harmonics) used by the launch vehicle, the ground stations and the spacecraft during launch operations and flight. This study is based upon the spacecraft frequency plan (including intermediate frequencies from 14 kHz to GHz) which has to be provided by the Customer. It also considers the impact of radiated emission caused by spacecraft or launch vehicle on RF communication capabilities.

The Customer is also requested to submit parameters of radio-telemetric equipment operating simultaneously with the *Rockot* transmission and reception systems during ground preparation, in flight and immediately after spacecraft deployment (before the *Rockot* transmission and reception systems are switched off). The Customer also has to provide limits for emissions and susceptibility regarding radiated disturbances. In case of conflict, the study will include an analysis of possible solutions related either to the launch vehicle or to the payload.

The housekeeping telemetry and telecommand of the payload may be subject to change upon EUROCKOT request up to 12 months before launch.

The final EMC study considers the actual configuration of the launch vehicle and spacecraft. The study involves the examination of possible spurious emission frequencies and the susceptible frequencies of the receivers.

8.6 Thermal Environment

The thermal environment study is implemented to show thermal compatibility throughout the mission. Using a thermal model provided by the Customer, this study covers the period from when the payload is integrated on the dispenser in the integration facility, up to spacecraft separation. The Customer has to provide a thermal model of the spacecraft containing:

- Description of the thermal nodes (heat capacities, mass type, etc.)
- Internal thermal couplings of nodes (conductive, radiative and convective)·
- Heat dissipation for all applicable modes of operation during the mission phases covered
- Interface descriptions (areas of contact, conductive and/or radiative properties)
- Thermal requirements for the environment to be maintained during integration, launch and flight

The detailed requirements of the spacecraft thermal model to be provided by the Customer are summarised in the EUROCKOT specification ESPE-0009. The preliminary thermal analysis must prove thermal compatibility of requirements and environmental conditions during the following phases or identify areas of concern where modifications have to be agreed upon for those phases:

- Operations within integration facilities
- Transportation to the launch pad
- Spacecraft integration on the *Rockot* launch vehicle
- Integrated phase until launch
- Ascent
- Aerothermal heating after fairing separation
- Coast phase

The final analysis will update the thermal compatibility study for all actual launch vehicle and spacecraft parameters.

8.7 Cleanliness Analysis

The standard cleanliness analysis is performed in two phases:

The preliminary contamination analysis must prove that accumulated contamination can be kept within the specified limits or identify areas of concern where improvements have to be agreed regarding the following contributions:

- Contamination of air used in clean rooms and under the fairing
- Outgassing and offgassing by spacecraft dispenser and fairing

- Contamination by activation of pyrotechnic devices
- Plume contamination during space separations
- Plume contamination by *Breeze* thrusters during orbit or attitude manoeuvres
- Plume contamination during collision avoidance after separation

The final analysis will confirm contamination compatibility for all actual launch vehicle and spacecraft parameters.

An additional contamination analysis can be performed optionally if requested by the Customer.

It will show compatibility regarding contamination accumulated by the spacecraft during the relevant phases from first opening of the transport container at the MIK to spacecraft separation and collision avoidance manoeuvre. The study covers the period from when the payload is integrated on the dispenser in the integration facility, up to the spacecraft release.