NOMAD

NOMAD on ExoMars Trace Gas Orbiter 2016

Science Orbit Observation Rules

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0/0	27/09/2017	All	Creation of file
0/1	02/10/2017	All	Update following discussion at Ops/UVIS meeting 28/9/17
0/2	05/10/2017	All	Complete update following discussions by email.
0/3	06/10/2017	1	Small corrections
0/4	07/12/2017	2	Corrections to commissioning plan
0/6	28/01/2018	All	Revised commissioning plan
0/7	06/03/2018	All	Added extra observation types, revised commissioning plan to match reality
0/8	09/03/2018	All	Revised special orbit types, Ian and Bojan changes.

List of abbreviations

ACS	Atmospheric Chemistry Suite (ExoMars instrument)
AOB	Any Other Business
BIRA	Belgian Institute for Space Aeronomie
CaSSIS	Camera and Stereo Surface Imaging System (ExoMars instrument)
DDS	Data Dissimination Server
EDDS	EGOS Data Dissemination System (data server at ESOC)
EDM	Entry, Descent, Landing Demonstrator Module
ESA	European Space Agency
ESAC	European Space Astronomy Centre
ESOC	European Space Operations Centre
EXM	ExoMars, Exobiology on Mars (ESA & Roscosmos mission)
FREND	Fine Resolution Epithermal Neutron Detector (ExoMars instrument)
FS	Flight Spare Model
HK	Housekeeping
LNO	Limb Nadir and Occultation (NOMAD channel)
MCC	Mid Cruise Checkout
MCO	Mars Capture Orbit
MOR	Mission Operation Report
NEC	Near Earth Commissioning
NOMAD	Nadir and Occultation for Mars Discovery (ExoMars instrument)
OPS	Operations
OU	Open University, England
PFM	Protoflight Model
PSA	Planetary Science Archive
RF	Radio Frequency
S/C	Space-Craft
SMU	Spacecraft Management Unit
SO	Solar Occultation (NOMAD channel)
SWT	Science Working Team
TM	Telemetry
UVIS	Ultraviolet VISible (NOMAD channel)

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1 Introduction

1.1 Rationale

Planning all observations cannot be done manually; therefore most of the process must be automated using a set of agreed-upon rules. However a single rigid observation plan will not be sufficient, as it will not be able to account for the many variables that NOMAD will experience throughout the science phase. Any plan must:

- Satisfy the science requirements
- Account for variations in solar geometry (e.g. beta angle) and the effects of this on measurement types and timings within an orbit
- Allow for cooldown periods for LNO
- Account for orbits where nominal operations are blocked by other instruments (e.g. ACS occultations) or due to orbital mechanics (e.g. no eclipses).
- Perform calibrations and other non-nominal science observations

As a compromise between automation and flexibility, it is proposed that a set of generic observation templates are to be defined to provide a starting point onto which the detailed planning can be implemented. These orbit templates can be placed into a timeline to generate an initial observation plan, which can then be populated with specific observations.

The start/end times of all science observations must be determined from a simple geometric parameter e.g. from occultation eclipse tangent heights, terminator crossing points, or solar zenith angles (SZA).

1.2 Nominal Science Orbit Types

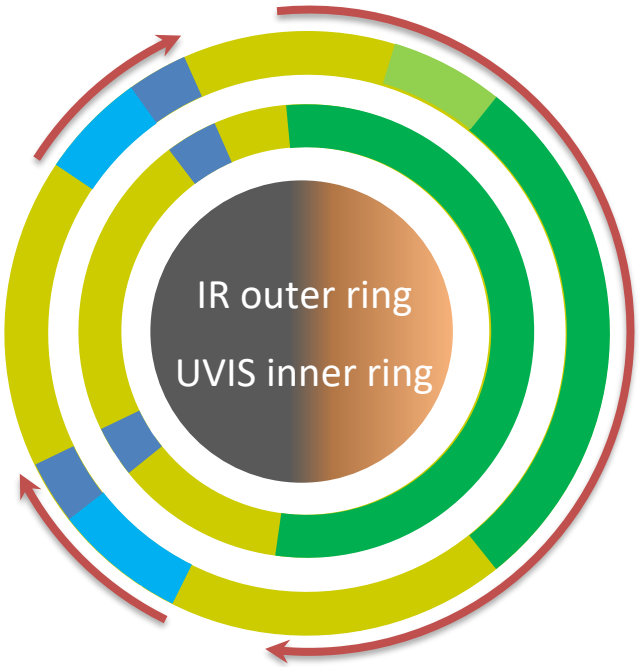
There are several generic observation templates that can be used throughout the mission. These are described below, and will account for the vast majority of all observations. It is currently assumed that SINBAD will remain on throughout and that UVIS is not constrained by any thermal rules. This simplifies the planning considerably; before additional observations were required for UVIS to perform measurements and the northern and southern poles, however these can now be removed from the nominal planning.

Note that here TGO is assumed to be moving from nightside southern hemisphere -> nightside northern hemisphere -> dayside northern hemisphere -> dayside southern hemisphere. For cases where the opposite is true, the observation sequence should be reversed.

If there is a timing conflict between a solar occultation and a nadir pointing block, the solar occultation always takes priority.

The red arrows indicate the TC20 durations.

1.2.1 Orbit Type 1: Nominal Science



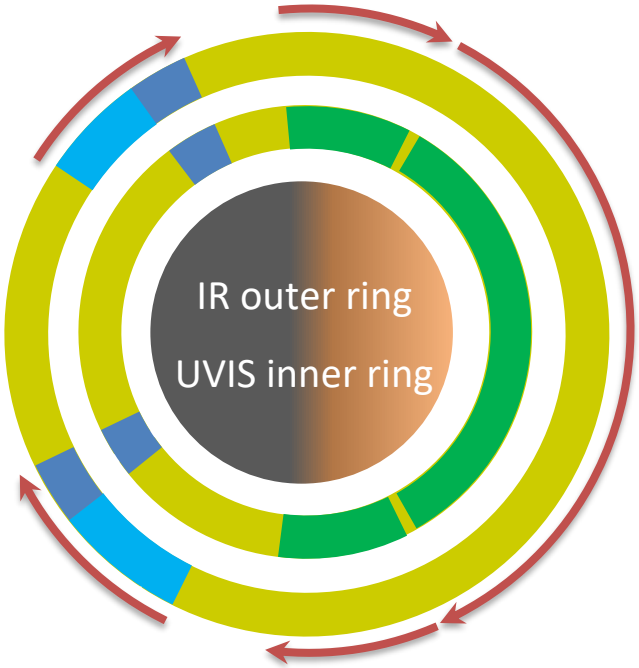
Precooling	Occultation
Precooling	Night nadir
Precooling	Day nadir
	Off

Nominal science

2x solar occultations
- SO+UVIS
- UVIS off for precooling

1x nadir
- UVIS on from northern terminator-2 minutes to southern terminator+2 minutes.
- LNO science is centred on the point of minimum phase angle (midpoint of observation). Total switch on time fit to thermal rule.

1.2.2 Orbit Type 2: LNO Cooldown Orbit



Precooling	Occultation
Precooling	Night nadir
Precooling	Day nadir
	Off

UVIS polar and nadir science

2x solar occultations
- SO+UVIS
- UVIS off for precooling

3x nadir
- UVIS on from northern terminator-2 minutes to 30 degrees north.
- UVIS on from 30 degrees north to 30 degrees south.
- UVIS on from 30 degrees south to southern terminator+2 minutes.
- LNO off throughout.

1.2.3 Orbit Type 3: No NOMAD Occultations

Precooling	Occultation
Precooling	Night nadir
Precooling	Day nadir
	Off

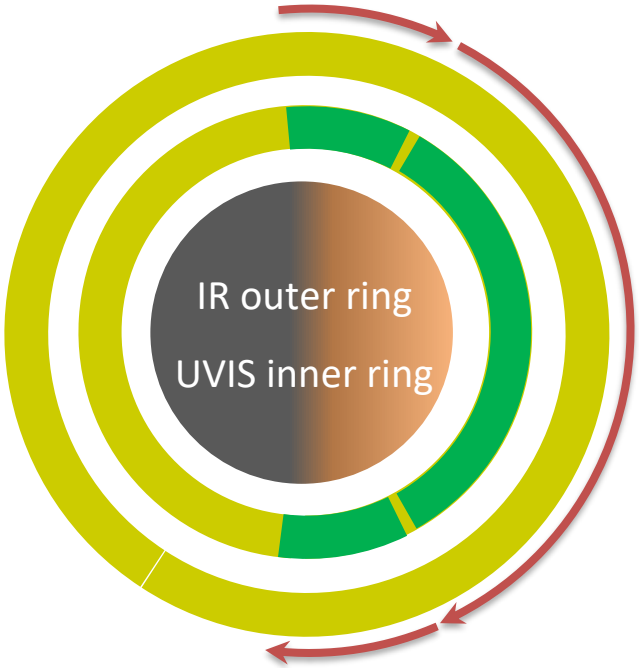
Dayside nadir science

No solar occultations

1x nadir

- LNO precooling and UVIS begin at northern terminator-12 minutes.
- LNO science from northern terminator-2 minutes to southern terminator+2 minutes (thermal rule does not apply here).

1.2.4 Orbit Type 4: No NOMAD Occultations, LNO Cooldown



Precooling	Occultation
Precooling	Night nadir
Precooling	Day nadir
	Off

UVIS polar and nadir science

No solar occultations

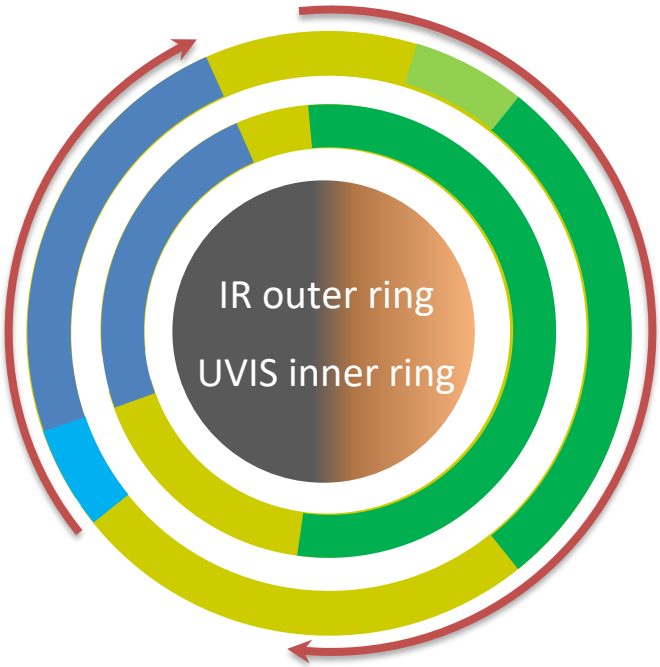
3x nadir

- UVIS on from northern terminator-2 minutes to 30 degrees north.
- UVIS on from 30 degrees north to 30 degrees south.
- UVIS on from 30 degrees south to southern terminator+2 minutes.
- LNO off throughout.

1.3 High Beta Angle Science

For certain measurements at high beta angles, ingress and egress occultations may need to be merged, or the tangent altitude may not reach the surface. At other times, the nominal science orbit types above will be used.

1.3.1 Orbit Type 5: Grazing / Merged Occultations



Precooling	Occultation
Precooling	Night nadir
Precooling	Day nadir
	Off

Long occultation science

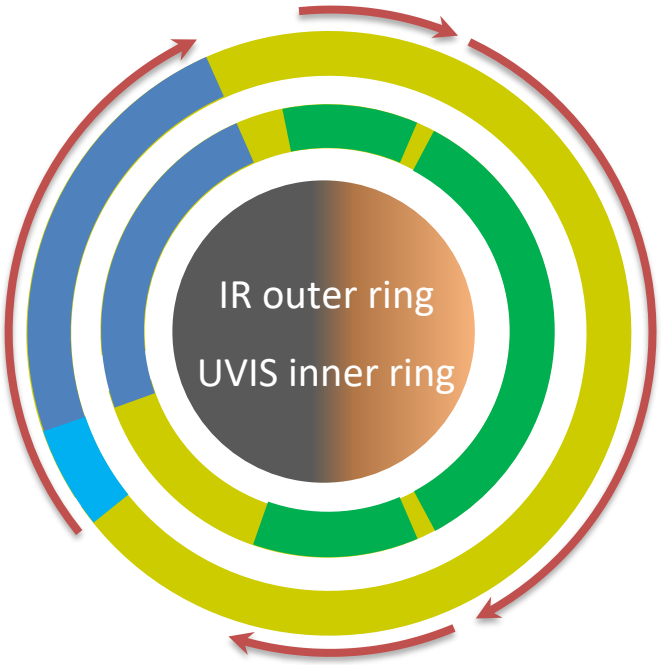
1x solar occultations

- SO+UVIS
- UVIS off for precooling

1x nadir

- UVIS on from northern terminator-2 minutes to southern terminator+2 minutes.
- LNO science is centred on the point of minimum phase angle (midpoint of observation). Total switch on time

1.3.2 Orbit Type 6: Grazing / Merged Occultations, LNO Cooldown



Precooling	Occultation
Precooling	Night nadir
Precooling	Day nadir
	Off

Long occultation science with LNO cooldown

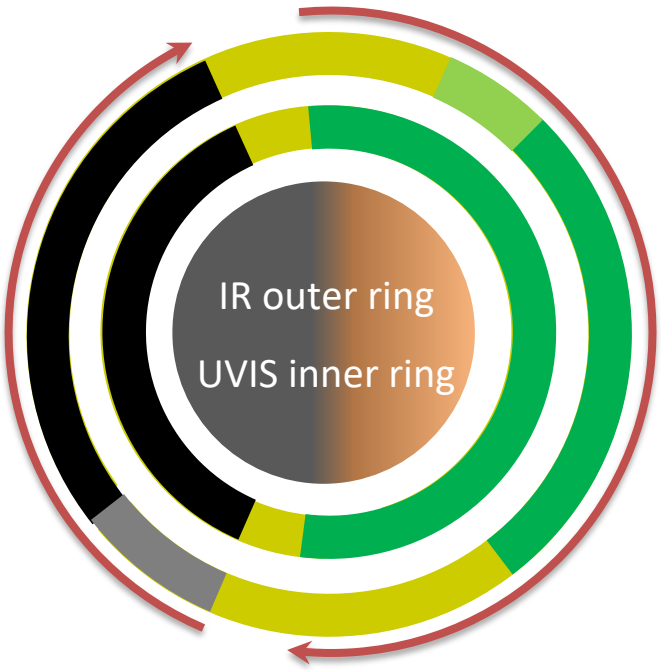
1x solar occultations
- SO+UVIS
- UVIS off for precooling

1x nadir
- UVIS on from northern terminator-2 minutes to 30 degrees north.
- UVIS on from 30 degrees north to 30 degrees south.
- UVIS on from 30 degrees south to southern terminator+2 minutes.
- LNO off throughout.

1.4 Special Orbit Types

These will be used occasionally to achieve specific science objectives. These should not be considered a part of the nominal science plan.

1.4.1 Orbit Type 7: No NOMAD Occultations, Day + Nightside Nadirs



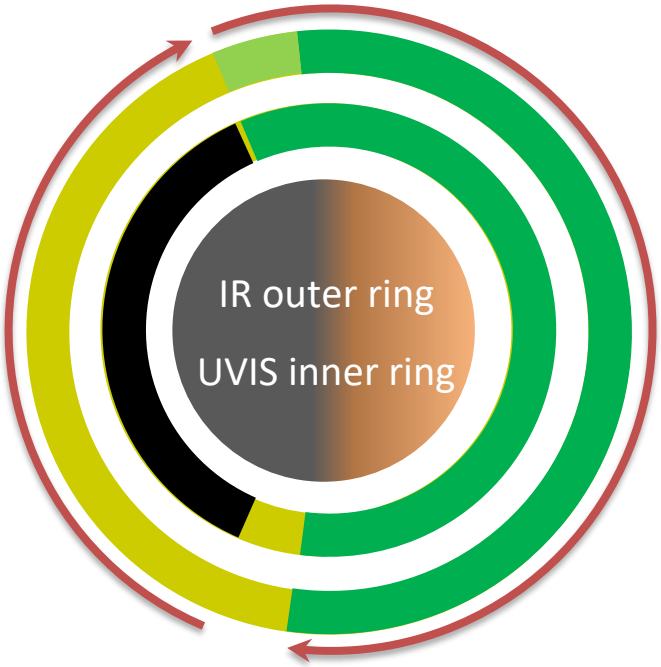
Precooling	Occultation
Precooling	Night nadir
Precooling	Day nadir
	Off

Nightside nadir science

No solar occultations
2x nadir

- UVIS and LNO nightside on from southern terminator+10 minutes to northern terminator-10 minutes.
- UVIS dayside on from northern terminator-2 minutes to southern terminator+2 minutes.
- LNO science is centred on the point of minimum phase angle (midpoint of observation).

1.4.2 Orbit Type 17: No NOMAD Occultations, UVIS Day + Nightside Nadir, LNO Dayside Nadir only

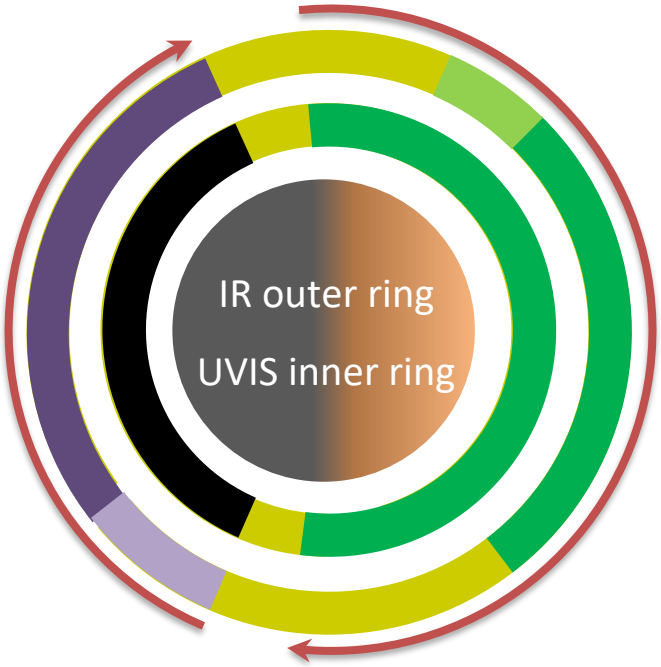


Precooling	Occultation
Precooling	Night nadir
Precooling	Day nadir
	Off

Nightside nadir science
No solar occultations
2x nadir

- UVIS nightside on from southern terminator+10 minutes to northern terminator-10 minutes.
- UVIS dayside on from northern terminator-12 minutes to southern terminator+2 minutes.
- LNO science is centred on the point of minimum phase angle (midpoint of observation).

1.4.3 Orbit Type 27: No NOMAD Occultations, UVIS Day + Nightside Nadir, LNO Nightside Limb + Dayside Nadir



Precooling	Occultation
Precooling	Night nadir
Precooling	Day nadir
	Off

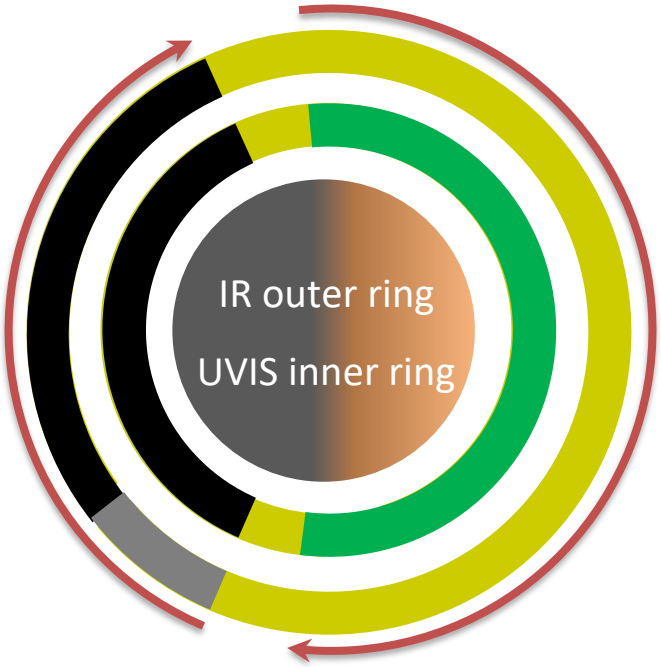
Nightside limb science
1x limb

- LNO nightside limb from southern terminator+10 minutes to northern terminator-10 minutes.

2x nadir

- UVIS nightside on from southern terminator+10 minutes to northern terminator-10 minutes.
- UVIS dayside on from northern terminator-2 minutes to southern terminator+2 minutes.
- LNO science is centred on the point of minimum phase angle (midpoint of observation).

~~1.4.4 Orbit Type 37: No NOMAD Occultations, LNO + UVIS Nightside Nadir, UVIS Dayside Nadir~~



Precooling	Occultation
Precooling	Night nadir
Precooling	Day nadir
	Off

~~Nightside nadir science~~

~~No solar occultations~~
~~2x nadir~~

- ~~UVIS and LNO nightside on from southern terminator+10 minutes to northern terminator-10 minutes.~~
- ~~UVIS dayside on from northern terminator-2 minutes to southern terminator+2 minutes.~~

1.4.5 Orbit Type 8: LNO Limb, UVIS nadir, no NOMAD Occultations

Precooling	Occultation
Precooling	Night nadir
Precooling	Day nadir
Precooling	Day limb
	Off

Limb science

No solar occultations
1x nadir

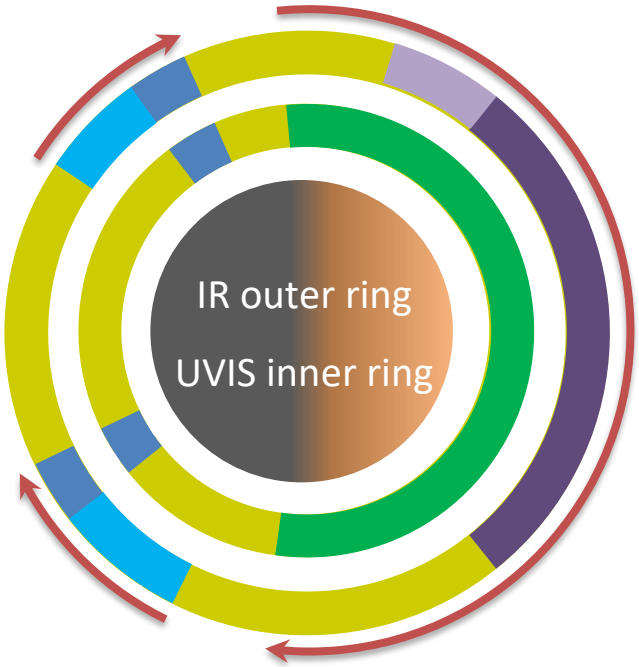
- UVIS begins at northern terminator-12 minutes

1x limb

- LNO precooling from terminator-12 minutes
- LNO science from northern terminator-2 minutes to southern terminator+2 minutes (thermal rule does not apply here).

1.4.6 Orbit Type 18: LNO Dayside Limb, UVIS Nadir, with Solar Occultations

This observation is dependent on the position of the Sun and so may need to be determined manually by the science team for specific orbits. 2x telecommands are required to move the LNO flip mirror to/from the solar position.



Precooling	Occultation
Precooling	Night nadir
Precooling	Day nadir
Precooling	Day limb
	Off

Limb science
2x solar occultations
- SO+UVIS
- UVIS off for precooling

1x nadir
- UVIS on from northern terminator-2 minutes to southern terminator+2 minutes.

1x limb
- LNO science is centred on the point of minimum phase angle (midpoint of observation). Total switch on time fit to thermal rule.

1.4.7 Orbit Type 28: True LNO + UVIS nadir with TGO rotation to limb (TBD)

This is currently forbidden by the spacecraft pointing rules, but could be useful in future planning cycles if allowed.

Precooling	Occultation
Precooling	Night nadir
Precooling	Day nadir
Precooling	Day limb
	Off

Limb science
No flip mirror change required
No solar occultations
1x limb

- UVIS begins at northern terminator-12 minutes
- LNO precooling from terminator-12 minutes
- LNO science from northern terminator-2 minutes to southern terminator+2 minutes (thermal rule does not apply here).

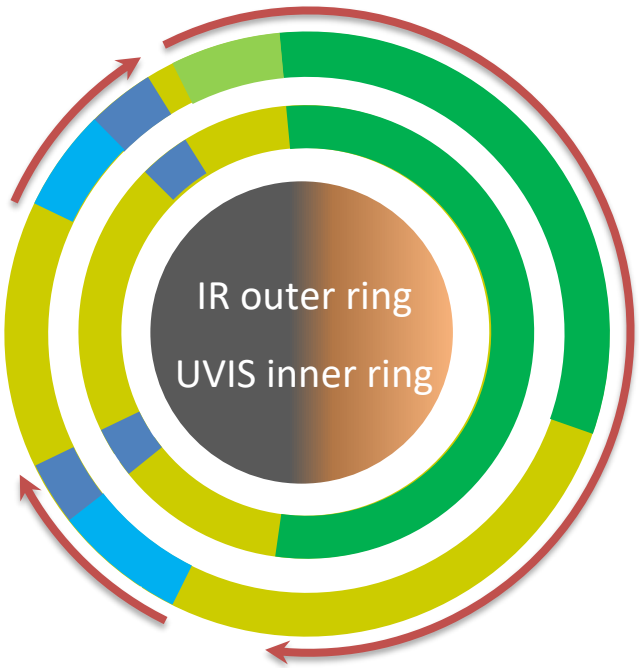
1.5 Calibration Orbit Types

1.5.1 Orbit Type 9: Solar Pointing Calibration

These will be scheduled during the no-eclipse seasons at high beta angle. Solar pointing blocks are required to perform the majority of these measurements – and hence cannot be planned until more is known about the spacecraft limitations. Solar pointing blocks of ~60 minutes each would be the preferred method of running these calibrations.

1.6 Other (TBD) Orbit Types

~~1.6.1 Orbit Type 10: LNO Northern Polar Science (TBD)~~



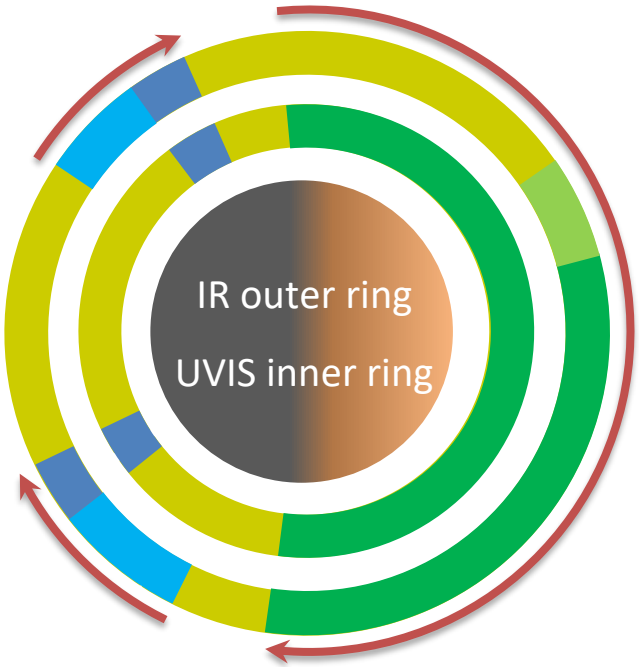
Precooling	Occultation
Precooling	Night nadir
Precooling	Day nadir
	Off

~~Northern polar science~~

~~2x solar occultations~~
- ~~SO+UVIS~~
- ~~UVIS off for precooling~~

~~1x nadir~~
- ~~UVIS on from northern terminator-2 minutes to southern terminator+2 minutes.~~
- ~~LNO on from northern terminator-2 minutes to mid-latitudes. LNO switch on duration fit to thermal rule~~

~~1.6.2 Orbit Type 11: LNO Southern Polar Science (TBD)~~



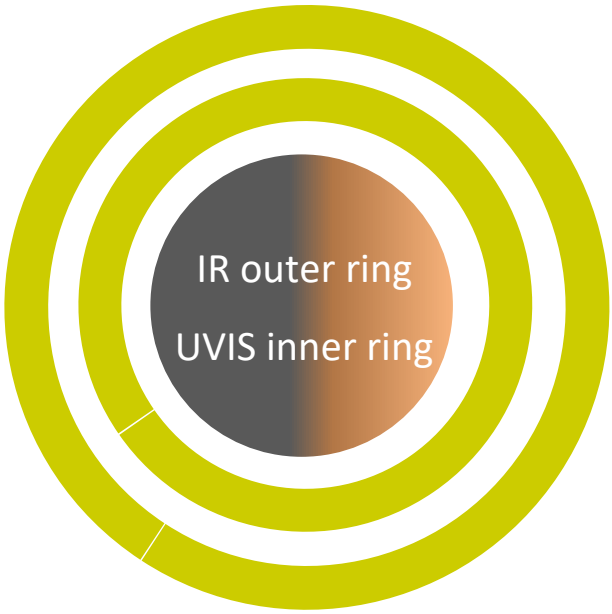
Precooling	Occultation
Precooling	Night nadir
Precooling	Day nadir
	Off

~~Southern polar science~~

~~2x solar occultations~~
- ~~SO+UVIS~~
- ~~UVIS off for precooling~~

~~1x nadir~~
- ~~UVIS on from northern terminator-2 minutes to southern terminator+2 minutes.~~
- ~~LNO on from mid-latitudes to northern terminator+2 minutes. LNO switch on duration fit to thermal rule~~

1.6.3 Orbit Type 12/OFF: NOMAD Off



Precooling	Occultation
Precooling	Night nadir
Precooling	Day nadir
	Off

- NOMAD off, no science.

1.7 Orbit Template Recap

- **OT1: Nominal science**
  - 2x SO+UVIS solar occultations
  - LNO mid-latitude dayside nadir
  - UVIS full dayside nadir
  - LNO cooldown periods on nightside and around north and south poles

- **OT2: LNO cooldown**
  - 2x SO+UVIS solar occultations
  - UVIS full dayside nadir
  - LNO cooldown periods on nightside, complete dayside, and around north and south poles

- **OT3: No occultations**
  - LNO+UVIS full dayside nadir
  - LNO cooldown periods on complete nightside

- **OT4: No occultations, LNO cooldown**
  - UVIS northern polar nadir
  - UVIS dayside nadir
  - UVIS southern polar nadir

- **OT5: Long occultation**
  - 1x SO+UVIS solar occultation
  - LNO mid-latitude dayside nadir
  - UVIS full dayside nadir

- LNO cooldown periods around north and south poles

- **OT6: Long occultation, LNO cooldown**
  - 1x SO+UVIS solar occultation
  - UVIS full dayside nadir
  - LNO cooldown periods on complete dayside and around north and south poles

- **OT7: Day and Nightside nadirs**
  - LNO+UVIS mid-latitude nightside nadir
  - LNO mid-latitude dayside nadir
  - UVIS full dayside nadir
  - LNO cooldown periods around north and south poles

- **OT17: UVIS day and nightside nadir, LNO dayside nadir only**
  - UVIS mid-latitude nightside nadir
  - LNO mid-latitude dayside nadir
  - UVIS full dayside nadir

- **OT27: UVIS day and nightside nadir, LNO dayside nadir and nightside limb**
  - LNO mid-latitude nightside limb
  - UVIS mid-latitude nightside nadir
  - LNO mid-latitude dayside nadir
  - UVIS full dayside nadir
  - LNO cooldown periods around north and south poles

- **OT37: UVIS day and nightside nadir, LNO nightside nadir only**
  - LNO+UVIS mid-latitude nightside nadir
  - UVIS full dayside nadir

- **OT47: UVIS day and nightside nadir, LNO nightside limb only**
  - LNO mid-latitude nightside limb
  - UVIS mid-latitude nightside nadir
  - UVIS full dayside nadir

- **OT8: LNO dayside limb with occulations**
  - 2x SO+UVIS solar occultations
  - LNO mid-latitude dayside limb
  - UVIS full dayside nadir
  - LNO cooldown periods around north and south poles

- **OT18: LNO dayside limb, no occultations**
  - LNO full dayside limb
  - UVIS full dayside nadir
  - LNO cooldown periods on nightside and around north and south poles

- **OT28: LNO+UVIS true dayside limb, no occultations (TBD)**
  - LNO+UVIS full dayside limb
  - LNO cooldown periods on nightside

- **OT9: Solar calibration**
  - SO/LNO/UVIS solar pointing blocks

- ~~**OT10: LNO northern pole (TBD if required)**~~
  - ~~2x SO+UVIS solar occultations~~
  - ~~LNO north pole and mid-latitude dayside nadir~~

- ~~UVIS full dayside nadir~~
- ~~LNO cooldown periods on nightside and around dayside southern latitudes~~

- ~~**OT11: LNO southern pole (TBD if required)**~~
  - ~~2x SO+UVIS solar occultations~~
  - ~~LNO mid-latitude dayside and south pole nadir~~
  - ~~UVIS full dayside nadir~~
  - ~~LNO cooldown periods on nightside and around dayside northern latitudes~~

- **OT12/OFF: NOMAD off: no occultations, no nadirs**
  - Full cooldown orbit

2 Commissioning Phase

Before the nominal science mission begins, there will be a commissioning phase lasting 4-6 weeks in which TGO will operate in nadir mode only (no dedicated pointings).

This period presents an ideal time to determine the thermal constraints of NOMAD by running various configurations that could be used throughout the mission. To make the tests accurate, the SO channel will be run for the solar occultations, though the data will not be usable as the channel will not be pointed to the sun. Several configurations will be tested:

NOMAD thermal baseline orbits:

Day 1: SINBAD-UVIS observation thermal baseline.

OT:	4	4	4	4	4	4	4	4	4	4	4	3

SO-LNO cooldown test orbits:

Day 2: 2 orbits of nominal science, observing the 80:40 rule. SINBAD remains on throughout. UVIS dayside nadirs.

OT:	4	4	4	4	4	3	4	4	4	4	4	3

80:40 rule with 1/2 LNO cooldown orbits:

Day 3: 6 orbits of nominal science, observing the 80:40 rule with regular LNO cooldown orbits. SINBAD remains on throughout. UVIS dayside nadirs.

OT:	4	3	4	3	4	3	4	3	4	3	4	3

Day 4: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

80:40 rule with 1/3 LNO cooldown orbits:

Day 4.5: 8 orbits of nominal science, observing a 80:40 rule with regular LNO cooldown orbits. SINBAD remains on throughout. UVIS dayside nadirs.

OT:	4	3	3	4	3	3	4	3	3	4	3	3

Day 5.5: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

80:40 rule with no LNO cooldown orbits:

Day 6: 12 orbits of nominal science, observing a 80:40 rule. SINBAD remains on throughout. UVIS dayside nadirs.

OT:	3	3	3	3	3	3	3	3	3	3	3	3

Day 7: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

60:60 rule with 1/2 LNO cooldown orbits:

Day 7.5: 6 orbits of nominal science, observing the 60:60 rule with regular LNO cooldown orbits. SINBAD remains on throughout. UVIS dayside nadirs.

OT:	4	3	4	3	4	3	4	3	4	3	4	3

Day 8.5: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

60:60 rule with 1/3 LNO cooldown orbits:

Day 9: 8 orbits of nominal science, observing a 60:60 rule with regular LNO cooldown orbits. SINBAD remains on throughout. UVIS dayside nadirs.

OT:	4	3	3	4	3	3	4	3	3	4	3	3

Day 10: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

60:60 rule with no LNO cooldown orbits:

Day 10.5: 12 orbits of nominal science, observing a 60:60 rule. SINBAD remains on throughout. UVIS dayside nadirs.

OT:	3	3	3	3	3	3	3	3	3	3	3	3

Day 11.5: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

80:40 rule with 1/2 LNO cooldown orbits – SINBAD off:

Day 12: 6 orbits of nominal science, observing the 80:40 rule with regular LNO cooldown orbits. SINBAD off for non-operational orbits. UVIS dayside nadirs.

OT:	OFF	3	OFF	3	OFF	3	OFF	3	OFF	3	OFF	3

Day 13: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

80:40 rule with 1/3 LNO cooldown orbits – SINBAD off:

Day 13.5: 8 orbits of nominal science, observing a 80:40 rule with regular LNO cooldown orbits. SINBAD off for non-operational orbits. UVIS dayside nadirs.

OT:	OFF	3	3	OFF	3	3	OFF	3	3	OFF	3	3

Day 14.5: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

80:40 rule with no LNO cooldown orbits – SINBAD off:

Day 15: 12 orbits of nominal science, observing a 80:40 rule. SINBAD off when not observing. UVIS dayside nadirs.

OT:	3	3	3	3	3	3	3	3	3	3	3	3

Day 16: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

60:60 rule with 1/2 LNO cooldown orbits – SINBAD off:

Day 16.5: 6 orbits of nominal science, observing the 60:60 rule with regular LNO cooldown orbits. SINBAD off for non-operational orbits. UVIS dayside nadirs.

OT:	OFF	3	OFF	3	OFF	3	OFF	3	OFF	3	OFF	3

Day 17.5: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

60:60 rule with 1/3 LNO cooldown orbits – SINBAD off:

Day 18: 8 orbits of nominal science, observing a 60:60 rule with regular LNO cooldown orbits. SINBAD off for non-operational orbits. UVIS dayside nadirs.

OT:	OFF	3	3	OFF	3	3	OFF	3	3	OFF	3	3

Day 19: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

60:60 rule with no LNO cooldown orbits – SINBAD off:

Day 19.5: 12 orbits of nominal science, observing a 60:60 rule. SINBAD off when not observing. UVIS dayside nadirs.

OT:	3	3	3	3	3	3	3	3	3	3	3	3

Day 20.5: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

Test measurements:

Day 21: 6 orbits of nightside nadirs, observing a 80:40 rule with regular LNO cooldown orbits. 6 orbits of limb measurements, observing a 80:40 rule with regular LNO cooldown orbits. SINBAD remains on throughout.

OT:	37	37	4	37	37	4	8	8	4	8	8	4

Day 22: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

Measurement sequence repeats until end of commissioning phase:

Extra tests and calibrations could be foreseen during this phase, provided that they comply with the requirement that TGO is always nadir pointed. For example, dark calibrations could be performed on the nightside, or additional thermal tests (running channels for long periods) would be possible. For now, nothing extra is foreseen – and therefore the remainder of the commissioning phase is filled by repeating the start of the observation sequence i.e.

80:40 rule with 1/2 LNO cooldown orbits (repeated from above):

Day 22.5: 6 orbits of nominal science, observing the 80:40 rule with regular LNO cooldown orbits. SINBAD remains on throughout. UVIS dayside nadirs.

OT:	4	3	4	3	4	3	4	3	4	3	4	3

Day 23.5: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

80:40 rule with 1/3 LNO cooldown orbits (repeated from above):

Day 24: 8 orbits of nominal science, observing a 80:40 rule with regular LNO cooldown orbits. SINBAD remains on throughout. UVIS dayside nadirs.

OT:	4	3	3	4	3	3	4	3	3	4	3	3

Day 25: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

80:40 rule with no LNO cooldown orbits (repeated from above):

Day 25.5: 12 orbits of nominal science, observing a 80:40 rule. SINBAD remains on throughout. UVIS dayside nadirs.

OT:	3	3	3	3	3	3	3	3	3	3	3	3

Day 26.5: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

60:60 rule with 1/2 LNO cooldown orbits(repeated from above):

Day 27: 6 orbits of nominal science, observing the 60:60 rule with regular LNO cooldown orbits. SINBAD remains on throughout. UVIS dayside nadirs.

OT:	4	3	4	3	4	3	4	3	4	3	4	3

Day 28: 6 orbits of thermal baseline cooldown.

OT:	4	4	4	4	4	4

60:60 rule with 1/3 LNO cooldown orbits:

Day 28.5: 5 orbits of nominal science, observing a 60:60 rule with regular LNO cooldown orbits. SINBAD remains on throughout. UVIS dayside nadirs.

OT:	4	3	3	4	3	3	4	3	END OF MTP

3 Example Observation Plans

Observation plans will be determined by the science team, comprising of a sequential list of orbit types. Several potential observation plans are given below.

3.1 Low Beta Angle (~0-30 degrees)

This regime accounts for approximately 50% of all orbits. Here the two occultations are ~20-30 minutes apart and the SZA is small on the dayside.

NOMAD will be allocated solar occultations on 2/3 of the orbits, therefore a measurement schedule could be as follows. The 80:40 rule can be applied until the commissioning phase results are analysed:

OT:	1	1	4	1	1	4	1	1	4	1	1	4

3.2 Medium Beta Angle (~30-60 degrees)

Here the two occultations are closer together and the SZA has higher values on the dayside. No nightside nadirs will be performed between the two solar occultations. MBA1 or 2 polar measurement templates may need to be suspended due to SO channel precooling, hence there may be a reduction in measurements of either pole.

The SO channel requires 10 minutes of precooling before each occultation measurement, therefore if the duration between the occultations is smaller than this then the observations will be merged.
Observations can be split into five orbit templates:

NOMAD will be allocated solar occultations on 2/3 of the orbits, therefore a measurement schedule could be as follows. The 80:40 rule can be applied until the commissioning phase results are analysed:

OT:	1	1	4	1	1	4	1	1	4	1	1	4

If the occultations are merged then the following would be preferable:

OT:	5	5	4	5	5	4	5	5	4	5	5	4

3.3 High Beta Angle (~60+ degrees)

Here the occultation tangent height never reaches 0km and TGO is always illuminated by the Sun. Atmospheric measurements can be made if the tangent height drops below TBD km, otherwise solar calibration measurements e.g. miniscans and fullscans should be run instead. The SZA is very high for nadir observations, reducing SNR of dayside nadir measurements, therefore the flip mirror could be used to perform LNO limb measurements if the solar geometry is suitable.

NOMAD will be allocated solar occultations on 2/3 of the orbits, therefore a measurement schedule could be as follows. The 80:40 rule can be applied until the commissioning phase results are analysed:

OT:	1	1	4	1	1	4	1	1	4	1	1	4

If the occultations are merged then the following would be preferable:

OT:	5	5	4	5	5	4	5	5	4	5	5	4

If the tangent height is high, nadir-only measurements could be made instead:

OT:	3	3	4	3	3	4	3	3	4	3	3	4

Or calibration measurements could be considered, depending on the length of time since the previous calibration campaign:

OT:	9	9	9	9	9	9	9	9	9	9	9	9

Calibration or limb measurements will likely be scheduled manually: the science team will provide a list of calibration observations, including a complete TC20 and a pointing type (e.g. solar pointing SO boresight), once an estimate of the time available has been estimated. If all measurements cannot be made in the allocated time the science team will be informed and a reduced list will be provided (and likewise if there is time available for additional measurements).

4 Scheduling Rules

- Solar occultations always have the highest priority if the tangent point passes below an altitude of TBD km. Each occultation begins at a height of (250 km minus 30 seconds) and ends at (0 km plus 30 seconds). This time is reserved first. The transition from SCIENCE1 to SCIENCE2 will be made at TBD km, and the TC20 times will be calculated using this rule. Should this become a variable, the modification of the timing parameters will be the responsibility of the science team.
- Next the occultation precooling period(s) of 10 minutes per occultation is scheduled. If there is less than 11 minutes between two occultation observations then the two occultations are merged into one. UVIS will be off for the occultation precooling period.
- The remaining time is allocated to the nadir observation, respecting the on-off time rules defined during testing. The observation start and end times are dependent on which template, however all timings are calculated from the terminator crossing times and thermal rule.
- ~~If there is a period of longer than TBD minutes where all channels are switched off, and NOMAD is not limited to a small number of TCs, SINBAD should be switched off so that the infrared channels have time to cool.~~

5 Data Volume Considerations

- Following the observation scheduling using the templates (above), data rates will be calculated assuming the following baseline parameters:
    - SO occultation: 24 lines; 1 second rhythm
    - LNO nadir or limb: 24 lines; 15 second rhythm
    - UVIS occultation: TBD per second
    - UVIS nadir: TBD per second (not full frame)
    - SO/LNO solar pointing calibrations: 24 lines; 1 second rhythm

- Other SO/LNO calibrations: TBD

- Orbits where the LNO channel is switched off can be included in the first calculation, once the thermal constraints have been analysed.
- The estimated data volume, following the above rules, and the volume allocated to NOMAD by the project will be communicated to the science team.
    - If the data volume exceeds the NOMAD allocation, the science team will decide which observations are to be removed/modified and a new list of observations (including start times and/or full TC20s) will be provided by the science team. Priority will always be made to solar occultations; however in the case of very low data volumes (around solar conjunction) the SO channel can be run on a rhythm of 2 seconds if absolutely necessary. If long grazing occultations occur around solar conjunction, start/end times may be modified. However it is very likely that nadir observations will be sacrificed first.
    - If the allocated data volume is underutilised, the science team will modify the TC20 values accordingly. SO and LNO TCs are very unlikely to be modified, however UVIS may choose to run in full frame mode for some nadir observations, up to a limit defined by the data allocation. A modified list of observations will be sent to the operations team for checking.
- The operations team should then run some TBD checks e.g. inputting the new plan into MAPPS.
- The required files will be generated and sent to SOC/MOC as appropriate.

6 Error Checking/Detection of Observations Clashes

6.1 Likely issues

- Clashes between solar occultation precooling and nadir polar observations
- Incorporating targeted observations e.g. Mars rovers into the planning
- Planning of other instruments e.g. CaSSIS off-nadir pointing requests
- TGO manoeuvres are not yet accounted for in the planning. Regular stoppages will be required but are currently unknown. It is unclear how solar calibrations will be scheduled when beta angle is high
- TGO and other instrument illumination constraints e.g. CaSSIS pointing vs. solar illumination angle

7 Other issues

Turn-around time from commissioning phase to implementation of on/off timing rule. Baseline is 80 minutes on: 40 minutes off, but this may result in the LNO channel running hot.

8 Appendix

8.1 LNO Flip Mirror

Each flip mirror change requires a single TC70. LNO will not be used for solar occultations, and therefore the flip mirror can remain in nadir position throughout. It should be moved only before and after a limb measurement or before/after a calibration campaign.

8.2 Note Regarding Telecommand Upload Limit

8.2.1 Adhering to the current limit

Note that this assumes unlimited TCs. If this is not the case then the plan will need to be modified to reduce the number of observations. In particular, if the current limit (750 TCs per 5 day period) is to be kept then switching SINBAD off for regular cool-down periods will never be possible.

Each measurement requires 3 TCs:

- *Open PDHU*
- *Send TC20*
- *Close PDHU*

Therefore 750 TCs per 5 days = 150 TCs per day = 12 TCs per orbit = 4 observations per orbit, not including LNO flip mirror manipulations.

8.2.2 Requirements for switching SINBAD on and off

The SINBAD switch on sequence requires 10 TCs, including the opening of the PDHU file
The SINBAD switch off sequence requires 12 TCs, including the closing of the PDHU file

Therefore to switch on+off fully once per orbit requires ~20 TCs per orbit = 240 TCs per day = 1200 TCs per 5 day period. The limit would need to be tripled to make this feasible.