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Philae Landing Preparations
A recall of what happened with a personal touch
ESTEC
10 January 2018

Joe.Zender@esa.int
Matt.Taylor@esa.int

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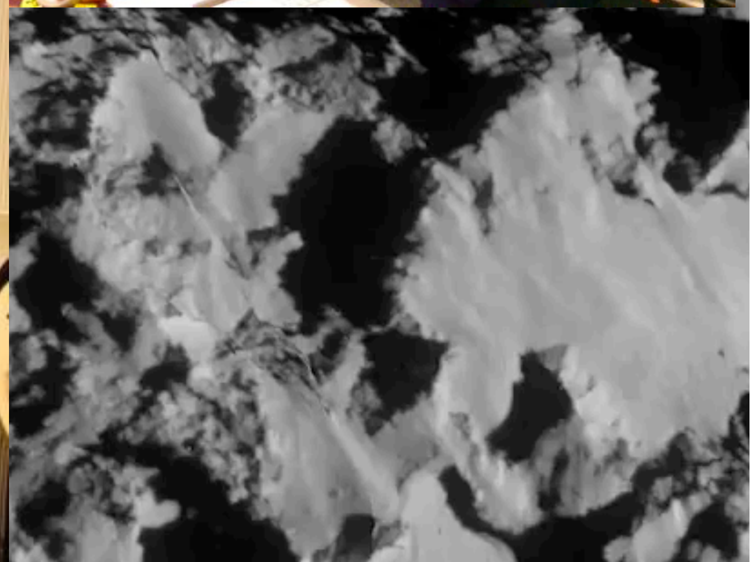
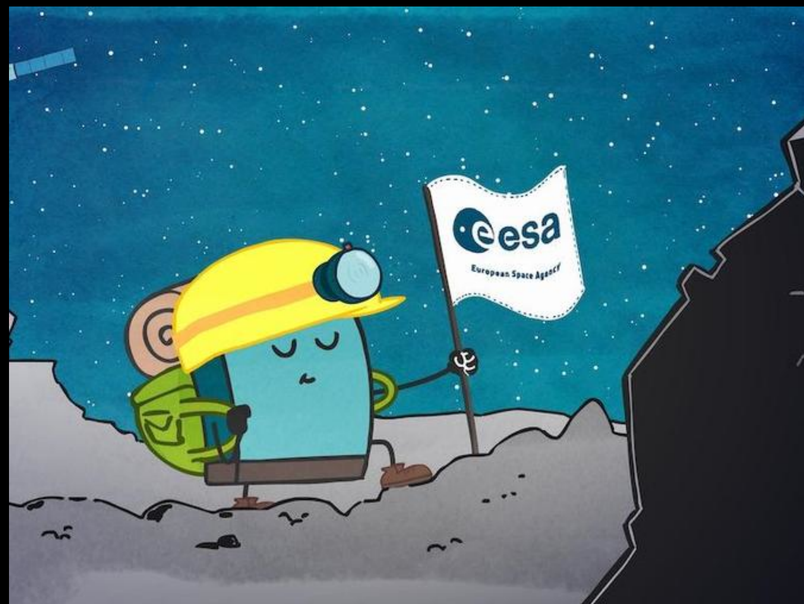
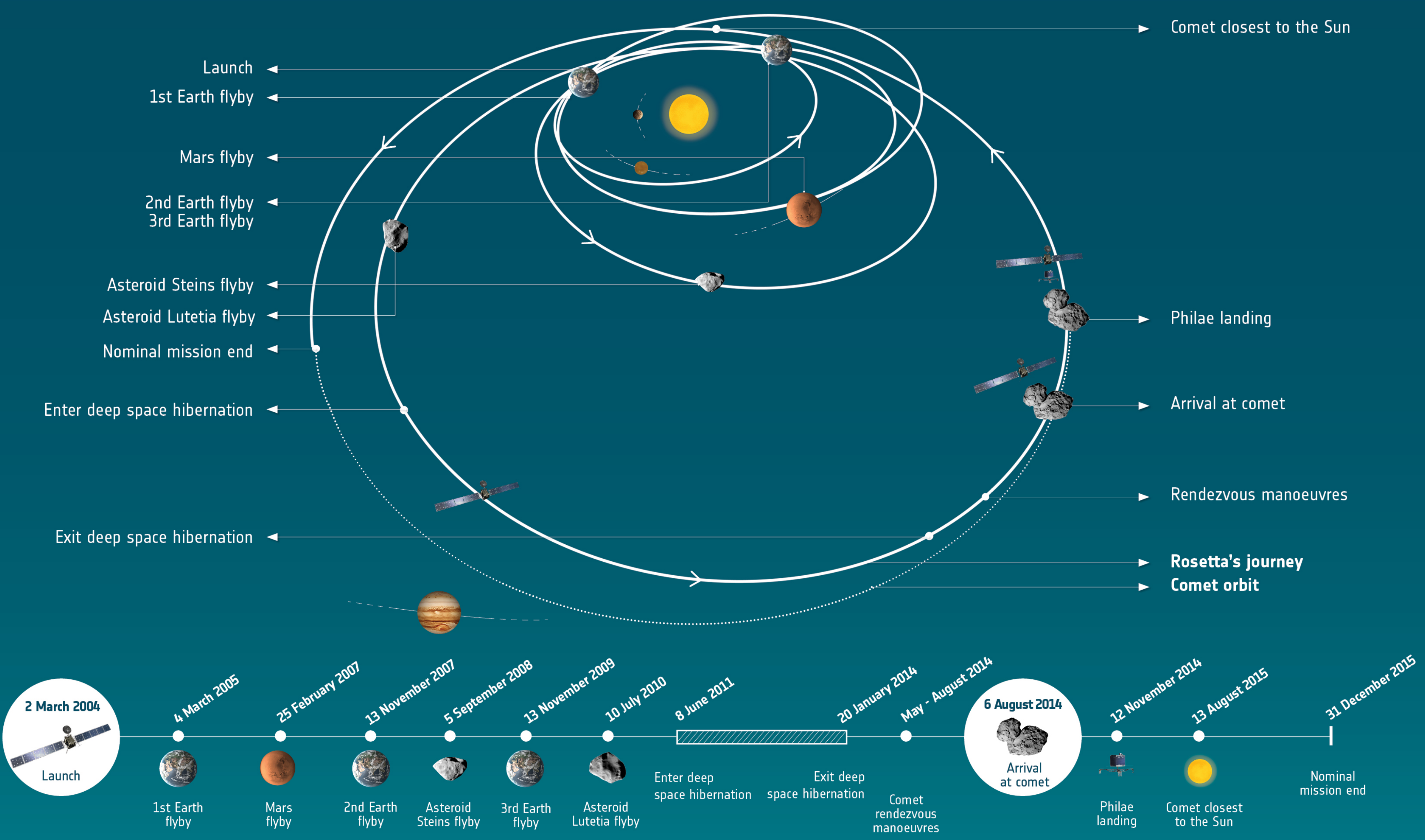


Outline

- The year 2014: remember what we did not know
- Our Schedule: step by step



→ ROSETTA'S JOURNEY



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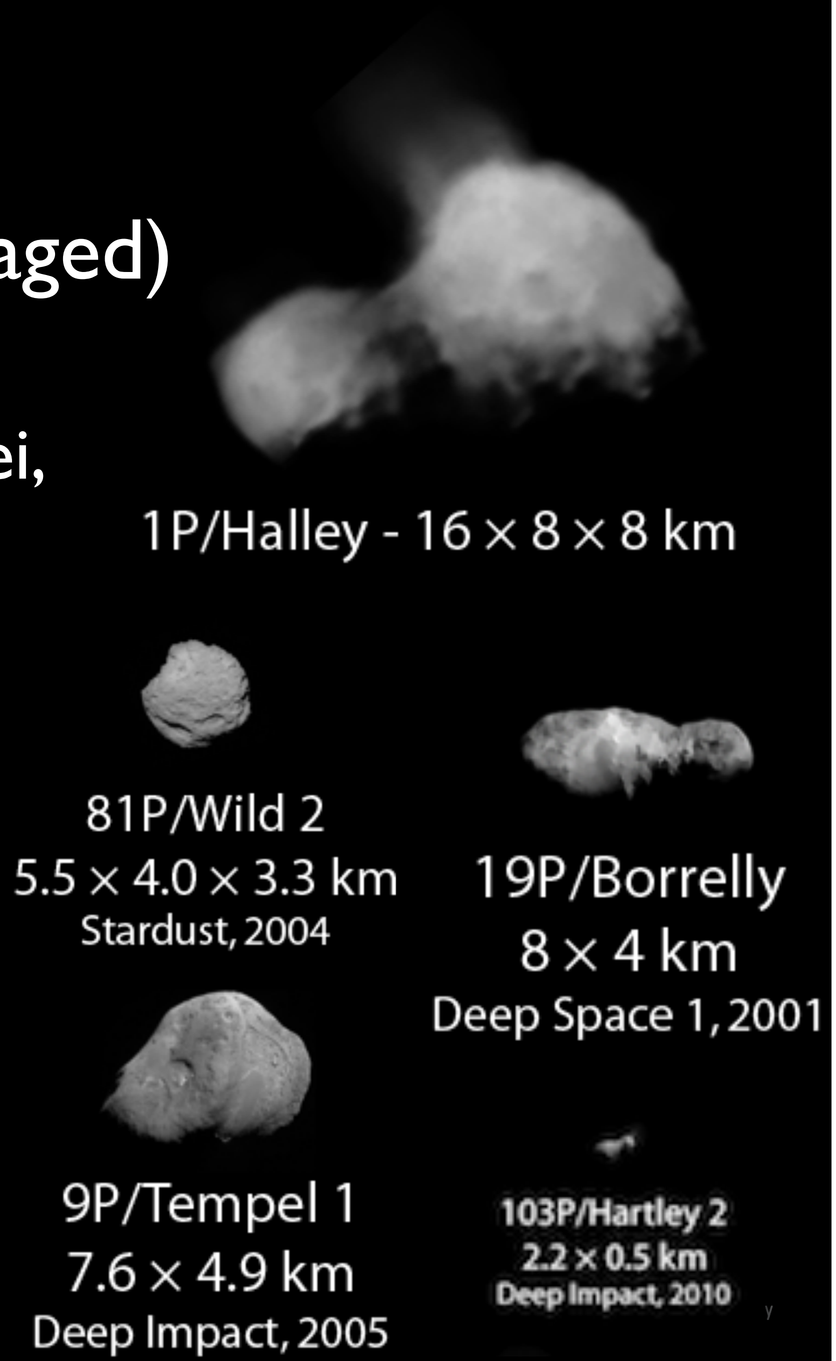
Spacecraft Visits to Comets (imaged)

- The Halley Armada
  - Giotto, Vega 1 and 2, Suisei, Sakigake
- Deep Space 1 (Borrelly)
- Stardust (Wild 2)
- Deep Impact (Tempel 1)
- EPOXI (Hartley 2)



Fly by's - 100's km
10's km/s

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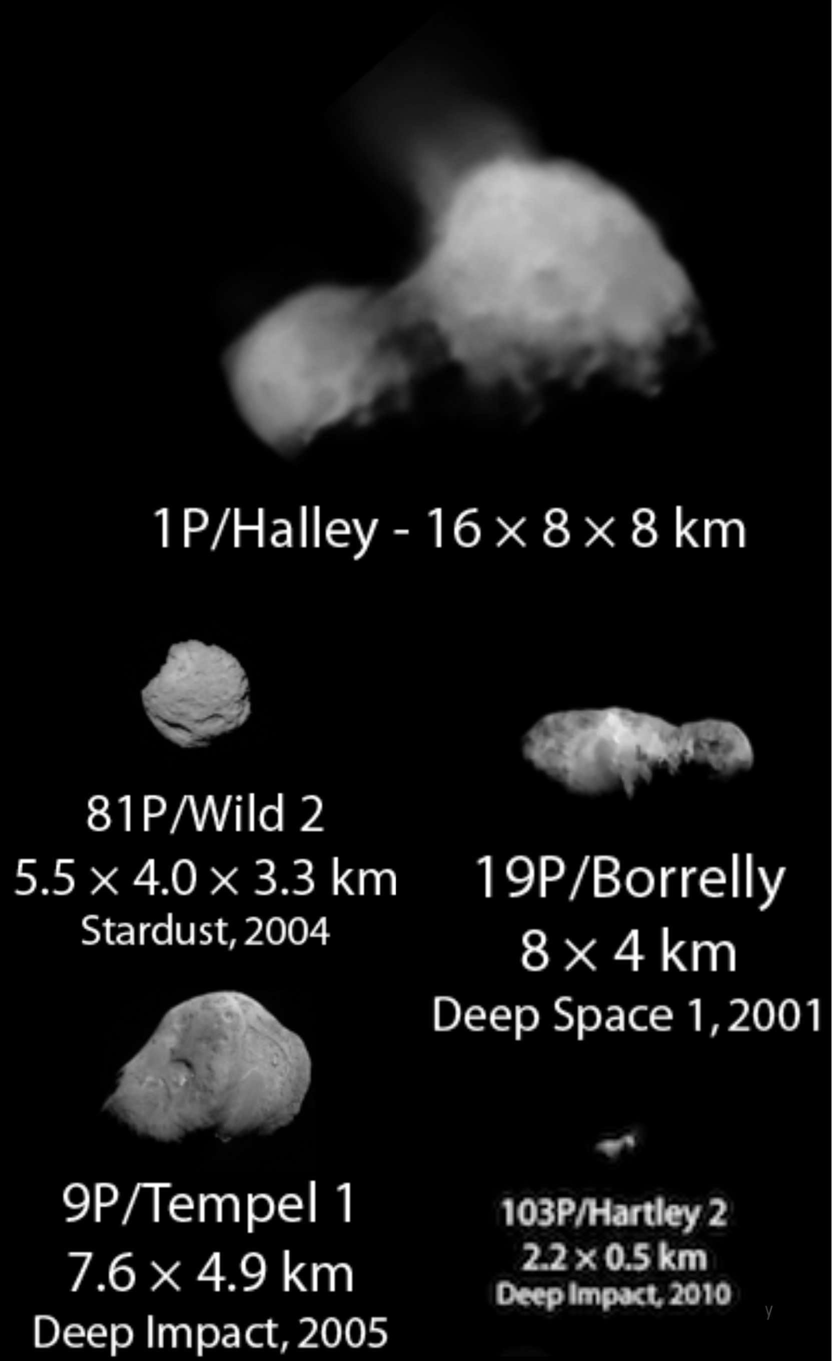
1P/Halley: Highly active, low albedo, relatively little geological information about the surface

19P/Borrelly: Diverse geology, different types of terrain, no ice found on surface!

81P/Wild: Rugged terrain, impact craters ?

9P/Tempel 1: Diverse terrain, primordial layers found?, impact craters ?, very little ice found on surface

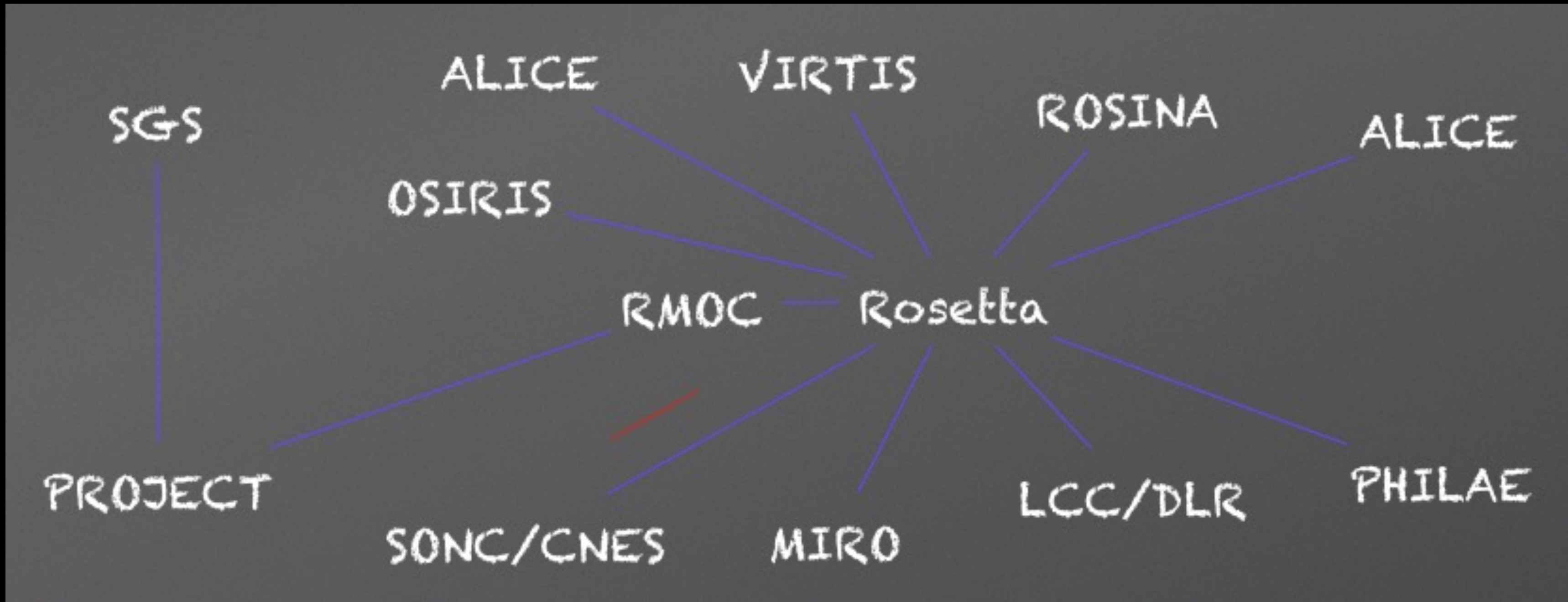
103P/Hartley 2: Hyperactive, diverse terrain, extreme shape, ice blocks (cm-dm sized) emitted from nucleus



My task:

Interface between the orbiter teams and the landing teams in all aspects of the landing site selection preparation.

"Identify crucial tasks and get them done."



ALICE
VIRTIS
SGS
ROSINA
ALICE
OSIRIS
RMOC
Rosetta
PROJECT
SONC/CNES
MIRO
LCC/DLR
PHILAE

Step-by-step

Collect information and talk to the teams:

20140206: telecon with OSIRIS camera team

20140207: telecon with ROSINA ion/neutral spectrometer team

20140207: telecon with VIRTIS UV-spectrometer team

20140214: telecon with MIRO IR-spectrometer team

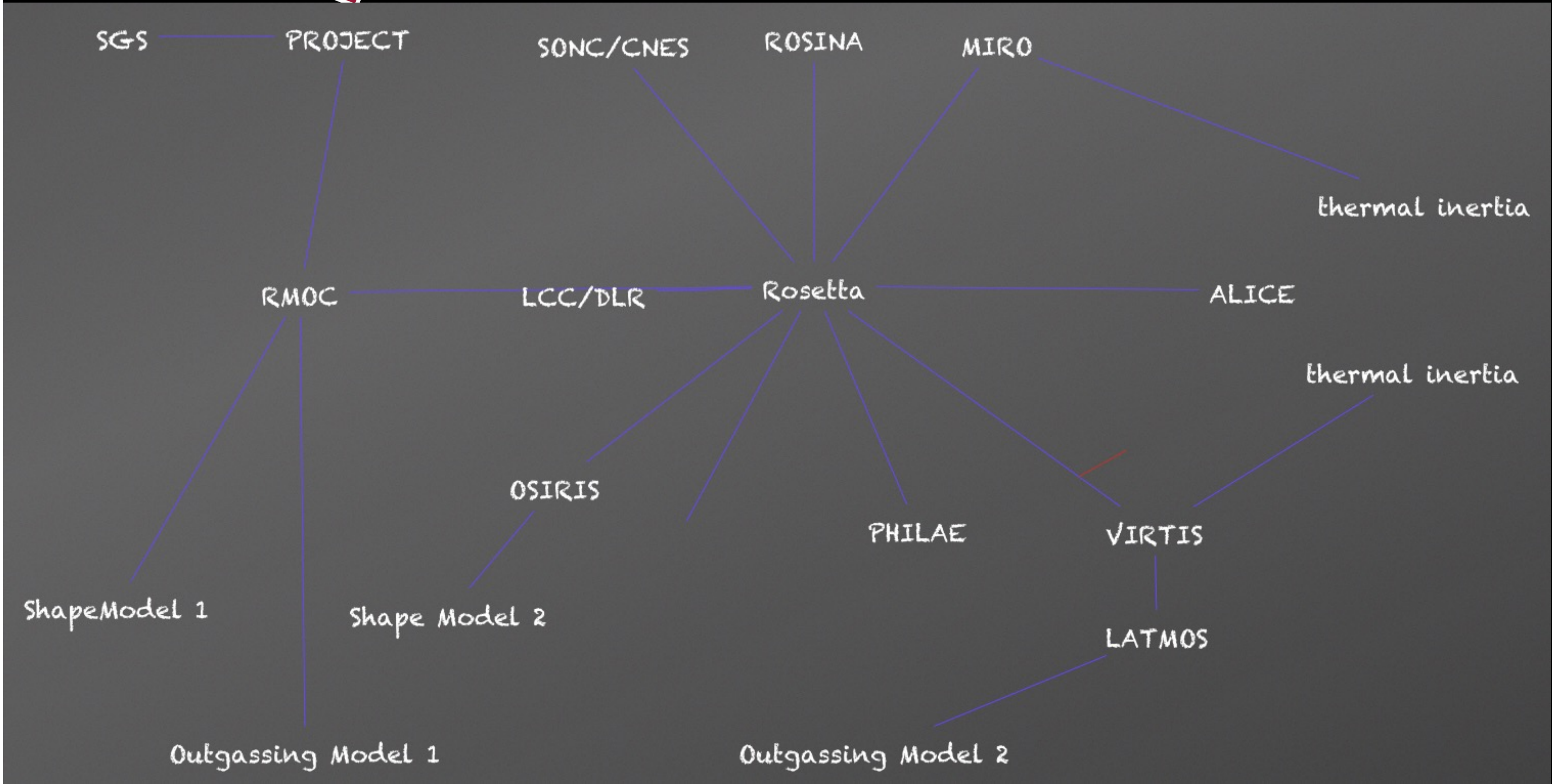
20140218: telecon with ALICE UV-spectrometer team

Step-by-step

20140310: Science Working Team meeting

- 2 outgassing models (RMOC, LATMOS)
- who will produce the thermal model? 2 candidates: MIRO or VIRTIS?
  - MIRO indicates that they miss the comet dark side shape information: it is not clear what the impact not the thermal model is.
  - MIRO asks, if the SONC needs the surface gas velocity or the surface gas velocity profile? Action item for SONC.

Date/Time	Room	Topic	Participants
Monday, 14:30	H168	RLLS Validation Test discussion	SONC RLGS SGS
Monday, 16:00	H168	RLLS Validation Test: test input data and	OSIRIS RLGS MOC SONC
TBC		OSIRIS derived SPICE kernels: needs and definition	BG,MAH
Monday 18:00	H168	Comet Surface Temperature Model (CSTM): input, model, responsibility	MIRO VIRTIS SONC RLGS
Wednesday 16:00 (TBC)		LATMOS interfaces	LATMOS SONC RLGS VIRTIS
Wednesday, 14:00		Coordinate Reference Frames	SGS MOC OSIRIS


SGS
PROJECT
SONC/CNES
ROSINA
MIRO
thermal inertia
RMOC
LCC/DLR
Rosetta
ALICE
thermal inertia
OSIRIS
PHILAE
VIRTIS
ShapeModel 1
Shape Model 2
LATMOS
Outgassing Model 1
Outgassing Model 2

Description	Action	Due Date
Model properties It was clarified that the RMOC model always solves for full (complex) rotation parameters. If the rotation is simple, this may be reflected in the parameters, but those parameters are not explicitly calculated. The origin of the coordinate system of the RMOC model is the centre of mass of the comet. The coordinate system may change slightly when the quality of the model is increased with increasing image resolution, but it will not be change arbitrarily when the model is updated. Flight dynamics pointed out that landmark positions are provided regularly both as Cartesian body-fixed coordinates and as pixel positions in images. The OSIRIS model will try to solve for simple rotation first and go for complex rotation if the residuals for simple rotation are larger than the error bars. In the OSIRIS shape model, the centre of the reference frame is the geometric centre of the shape. The difference between the centres in the two reference frames is expected to be insignificant (to be tested by OSIRIS). The OSIRIS model will use the rotation parameters from the RMOC model as a starting point for reconstruction. Those parameters may be (slightly) modified in the optimization process.		
Frame transformation between RMOC model and OSIRIS model:		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Camera NAVCAM1 20140608
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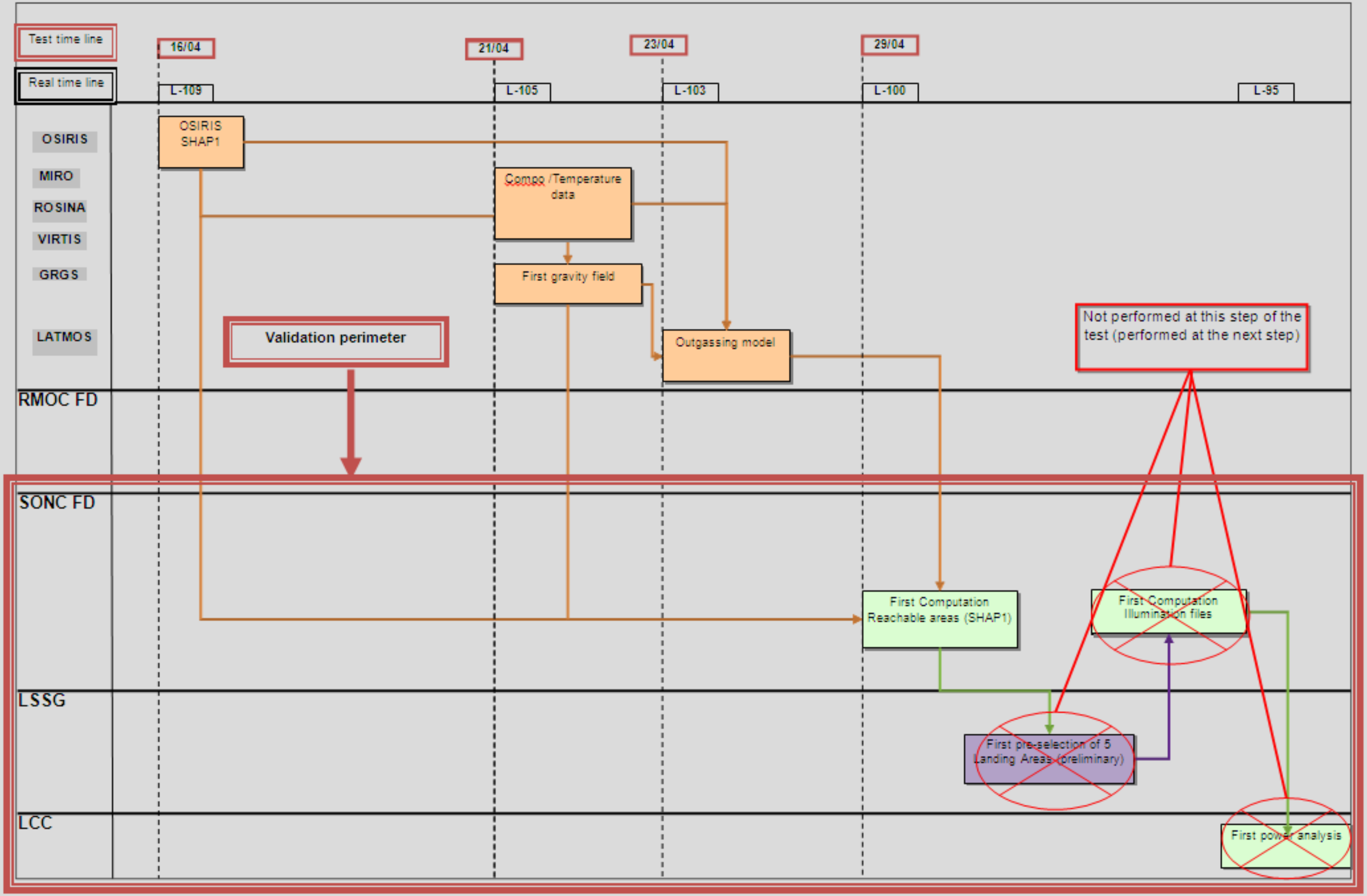
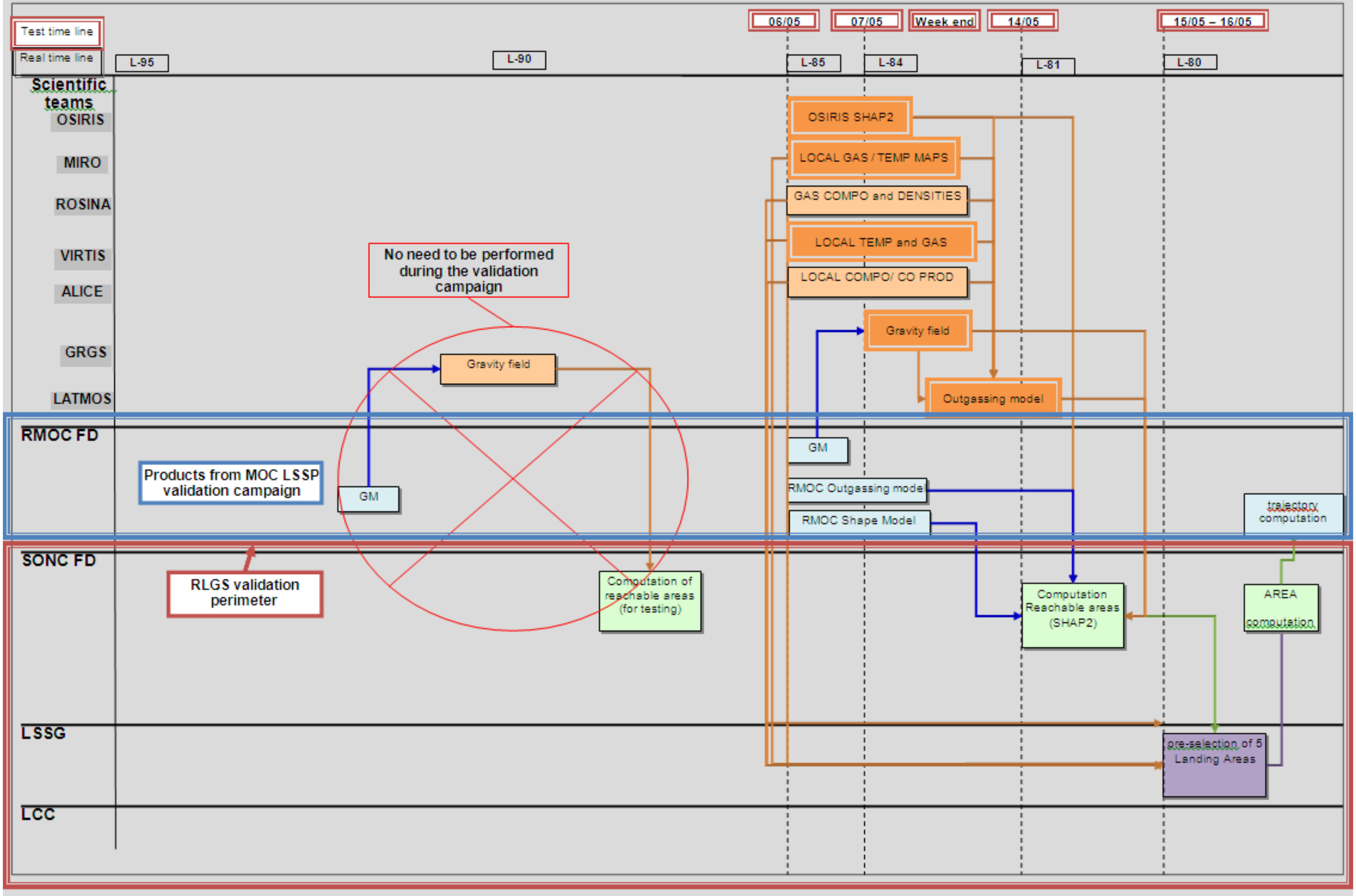
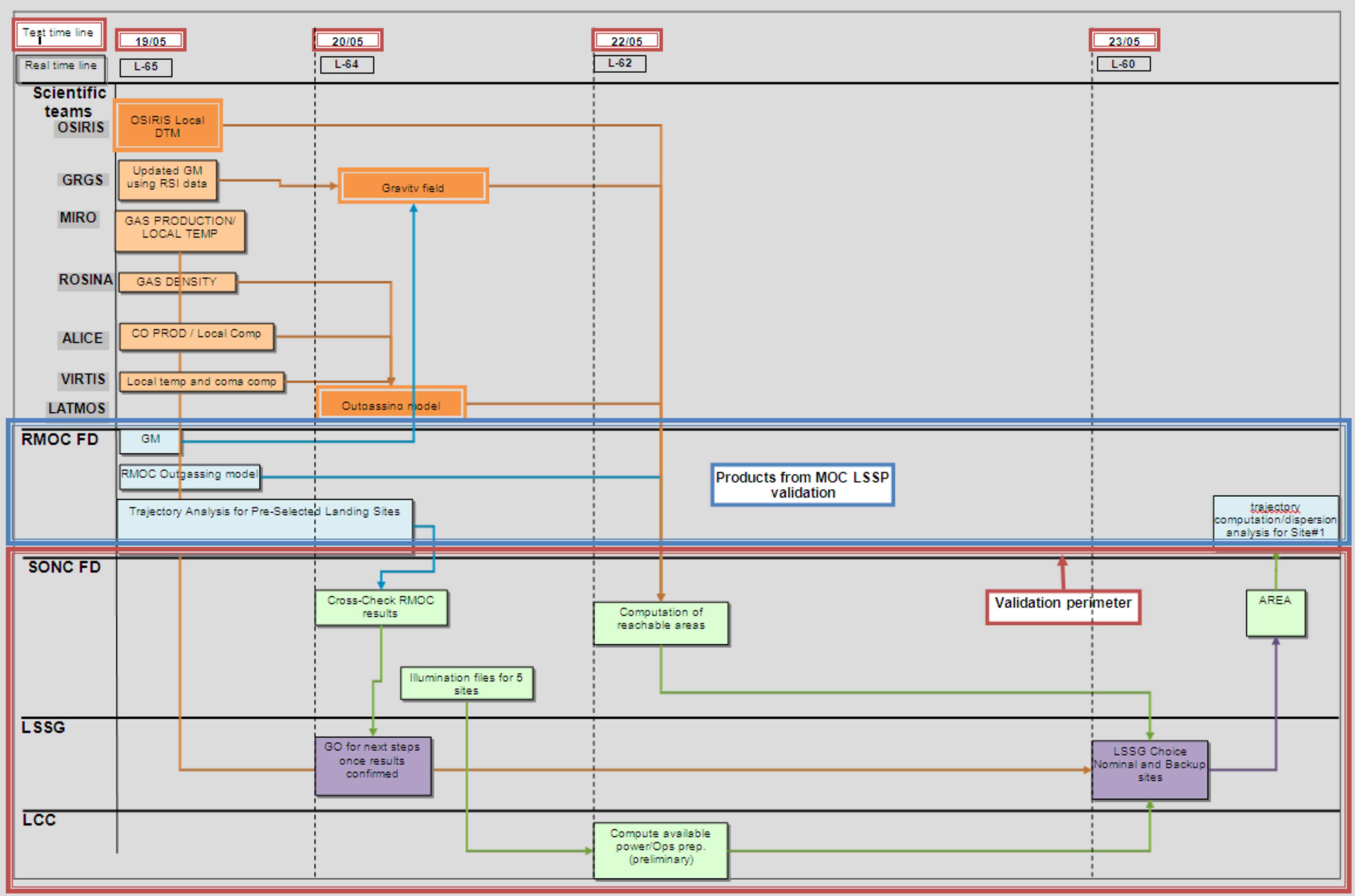
The Plan …. the Test Plan first … as seen by SONC in March 2014

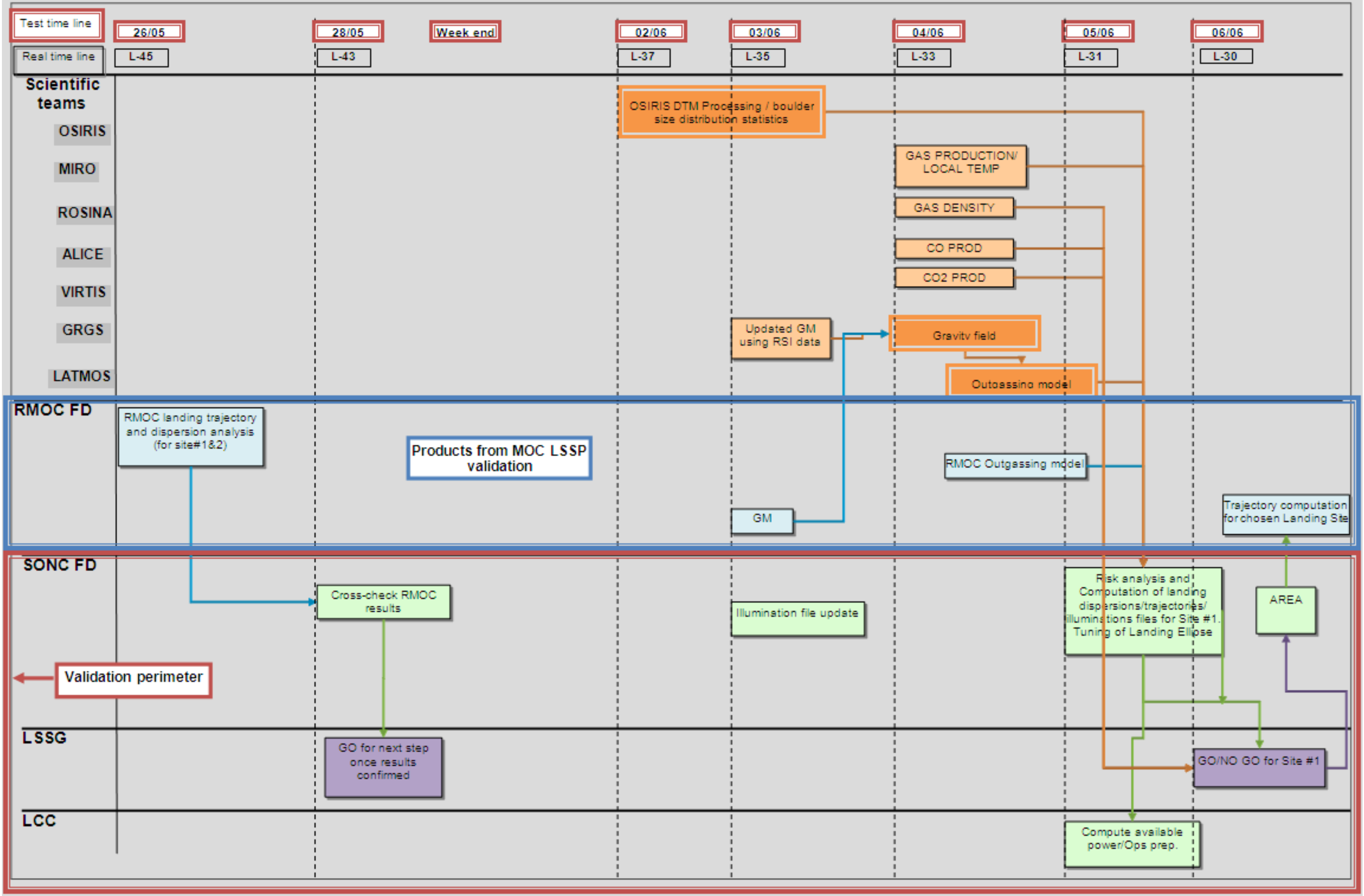

Test time line
Real time line
16/04
21/04
23/04
29/04
L-109
L-105
L-103
L-100
L-95
OSIRIS
MIRO
ROSINA
VIRTIS
GRGS
LATMOS
RMOC FD
SONC FD
LSSG
LCC
OSIRIS SHAP1
Compo /Temperature data
First gravity field
Outgassing model
Validation perimeter
Not performed at this step of the test (performed at the next step)
First Computation Reachable areas (SHAP1)
First Computation Illumination files
First pre-selection of 5 Landing Areas (preliminary)
First power analysis



Test time line
Real time line
06/05
07/05
Week end
14/05
15/05 – 16/05
L-95
L-90
L-85
L-84
L-81
L-80
Scientific teams
OSIRIS
MIRO
ROSINA
VIRTIS
ALICE
GRGS
LATMOS
RMOC FD
SONC FD
LSSG
LCC
OSIRIS SHAP2
LOCAL GAS / TEMP MAPS
GAS COMPO and DENSITIES
LOCAL TEMP and GAS
LOCAL COMPO/ CO PROD
Gravity field
Outgassing model
No need to be performed during the validation campaign
Gravity field
GM
Products from MOC LSSP validation campaign
GM
RMOC Outgassing model
RMOC Shape Model
trajectory computation
RLGS validation perimeter
Computation of reachable areas (for testing)
Computation Reachable areas (SHAP2)
AREA computation
pre-selection of 5 Landing Areas



Test time line
Real time line
19/05
L-65
20/05
L-64
22/05
L-62
23/05
L-60
Scientific teams
OSIRIS
GRGS
MIRO
ROSINA
ALICE
VIRTIS
LATMOS
OSIRIS Local DTM
Updated GM using RSI data
Gravity field
GAS PRODUCTION/ LOCAL TEMP
GAS DENSITY
CO PROD / Local Comp
Local temp and coma comp
Outgassing model
RMOC FD
GM
RMOC Outgassing model
Trajectory Analysis for Pre-Selected Landing Sites
Products from MOC LSSP validation
trajectory computation/dispersion analysis for Site#1
SONC FD
Cross-Check RMOC results
Computation of reachable areas
Validation perimeter
AREA
Illumination files for 5 sites
LSSG
GO for next steps once results confirmed
LSSG Choice Nominal and Backup sites
LCC
Compute available power/Ops prep. (preliminary)



Test time line
Real time line
26/05
L-45
28/05
L-43
Week end
02/06
L-37
03/06
L-35
04/06
L-33
05/06
L-31
06/06
L-30
Scientific teams
OSIRIS
MIRO
ROSINA
ALICE
VIRTIS
GRGS
LATMOS
OSIRIS DTM Processing / boulder size distribution statistics
GAS PRODUCTION/ LOCAL TEMP
GAS DENSITY
CO PROD
CO2 PROD
Updated GM using RSI data
Gravity field
Outgassing model
RMOC FD
RMOC landing trajectory and dispersion analysis (for site#1&2)
Products from MOC LSSP validation
RMOC Outgassing model
GM
Trajectory computation for chosen Landing Site
SONC FD
Cross-check RMOC results
Illumination file update
Risk analysis and Computation of landing dispersions/trajectories/ illuminations files for Site #1. Tuning of Landing Ellipse
AREA
Validation perimeter
LSSG
GO for next step once results confirmed
GO/NO GO for Site #1
LCC
Compute available power/Ops prep.

Road Map

- Clarification about the usable inputs (RMOC & PI products) => from now to end of March
  - Usable products have to be prepare as soon as possible in order to ensure their availability for other providers who need them, and to ensure their delivery when expected for the test,
- Finalization of LSSP test with RMOC => end of March
- Test plan update/finalization => end of March
- "Warm up" test (if possible) => during April
- Test Readiness Review => end April
- LSSP phase 1 validation => 06/05 to 16/05
- LSSP phase 2 validation => 19/05 to 23/05
- LSSP phase 3 validation => 26/05 to 06/06
- Post Test Review => mid June
- ESA LSSP Readiness Meeting => 01/07

Products (wrt ICDs)	Classification	Producer	Product available for test?
Shape model *"RS_GLOBAL_DTM_500m", "RS_GLOBAL_DTM_20m"*	SHAP1 important; SHAP2 & SHAP2MIRO **Mandatory**	OSIRIS	
rotational parameters/model *"RS_ROT_PARAM_500m", "RS_ROT_PARAM_20m", "RS_ROT_PARAM_LOCAL_DTM", "RS_ROT_PARAM_IMAGES_LS"*	**Mandatory**	OSIRIS	
Local DTM (3m resolution) *"RS_LOCAL_DTM"*	**Mandatory**	OSIRIS	
Images high resolution *"RS_IMAGES_LAND_SITE1", "RS_IMAGES_LAND_SITE2",*	**Mandatory**	OSIRIS	
obstacle size distribution *"RS_BOULDERS_LAND_SITE1, RS_BOULDERS_LAND_SITE2"*	**Mandatory**	OSIRIS	
Colormaps, composition *RS__GLOBAL_COMPOSITION", "RS_LOCAL_COMPOSITION"*	Important	OSIRIS	
Albedo map *"RS_ALBEDO_500m" "RS_ALBEDO_20m"*	Valuable	OSIRIS	
Dust and gas coma monitoring *"RS_MONITORYING_DUST_date", "RS_MONITORYING_GAS_date"*	Valuable	OSIRIS	
Inner coma monitoring *"RS_MONITORYING_INNER_COMA_date »*	Valuable	OSIRIS	
"Far global density measurements of H_2O, CO and CO_2", "	Important	ROSINA	

Products (wrt ICDs)	Classification	Producer	Product available for test?
"Global density measurements of H_2O, CO and CO_2"	Important	ROSINA	
"Close local measurements of H_2O, CO and CO_2"	Important	ROSINA	
"Global measurements of total gas density"	Important	ROSINA	
"Close local measurements of total gas density"	Important	ROSINA	
"Total density and gas dynamics measurements"	Important	ROSINA	
"Global Surface compos	Important	ALICE	
"Surface of Candidate Landing Sites"	Important	ALICE	
"Global CO Gas Production"	Important	ALICE	
"CO Gas Production at Candidate Landing Sites "	Important	ALICE	
"Surface composition"	Important	VIRTIS	
"Surface temperature predictions and thermal properties" (TI)	**Mandatory**	VIRTIS & MiRO	
"Coma composition"	Important	VIRTIS	
"Global H_2O and CO gas production rates	**Mandatory**	MIRO	
"Local gas production and variability"	Important	MIRO	
« Temperature predictions of nucleus » " (TI)	**Mandatory**	MIRO & VIRTIS	
"Temperature map of candidate landing sites	Important	MIRO	
"Gas production, velocity, and variability of candidate landing sites"	Important	MIRO	
"Antenna temperatures during selected night-time limb crossings"	Important	MIRO → Osiris	

from Jens Biele, LCC, March 2014

Landing Site Selection: Status of essential Orbiter Instrument Products

Product	Originator	Data Pipeline	Interface validation	E2E test preparation
20m Products	OSIRIS	in validation	Executed, awaiting confirmation, delta tests necessary	In preparation
3m Products	OSIRIS	In validation	Executed (ac)	In preparation
High-resolution images	OSIRIS	validated	Executed (ac)	Ready for test
List of boulders	OSIRIS	validated	Executed (ac)	Ready for test
Comet Surface Temp Model	VIRTIS/MIRO	In development	In preparation	In preparation
Gravity model	GRGS/CNES	No information	No information	No information
Outgassing model	LATMOS/CNES	No information	No information	No information

my own presentation from April 2014 at Steering Committee

Landing Site Selection:
Status of important Orbiter Instrument Products (not part of E2E test in May 2014)

Product	Originator	Data Pipeline	Interface validation
H20, CO and CO2 measurements	ROSINA	Validated	executed successfully
Gas density	ROSINA	Validated	Executed successfully
Surface composition (global/local)	ALICE	Validated	Ready for testing
CO gas production (global/local)	ALICE	Validated	Ready for testing
COMA composition	VIRTIS	validated	Executed successfully
Surface composition	VIRTIS	validated	Executed successfully
H20, CO gas production	MIRO	In development	Executed successfully
Temperature maps (global/local)	MIRO	In development	Executed successfully
	MIRO	In development	Executed

To get all the model output, one needs

first: to plan and acquire the data

second: to downlink the data

and third: to have good data and success with the computations.

and here is THE Plan … as seen from Project …

open 01-RO-SGS-LI-1014_1_3_LSSP_InputProductsOverview_20140730

Juni 2014

gebaseerd op
> Optische technieken (lightcurves) uit telescoop waarnemingen
> Thermische analyse en optische fotometrie
> Spitzer thermische IR data

We verwachten (bijv. Op basis van Lowry et al, 2012)

> Axiale ratio's: b / a = 1.239, p / a = 0,819 (7% marge)
> Spin rate: 12.76 uur
> Pol: lambda = 78 (+ -10) °, beta = 58 (+ -10) graden
> Nucleus fase verduistering: G = 0,11 (+ -0,12), Hr = 15,31 (+ - 0.07)
> Thermische inertie: <15 J / m2 / K / sqrt (s)

S. Lowry et al.: The Nucleus of Comet 67P/Churyumov-Gerasimenko

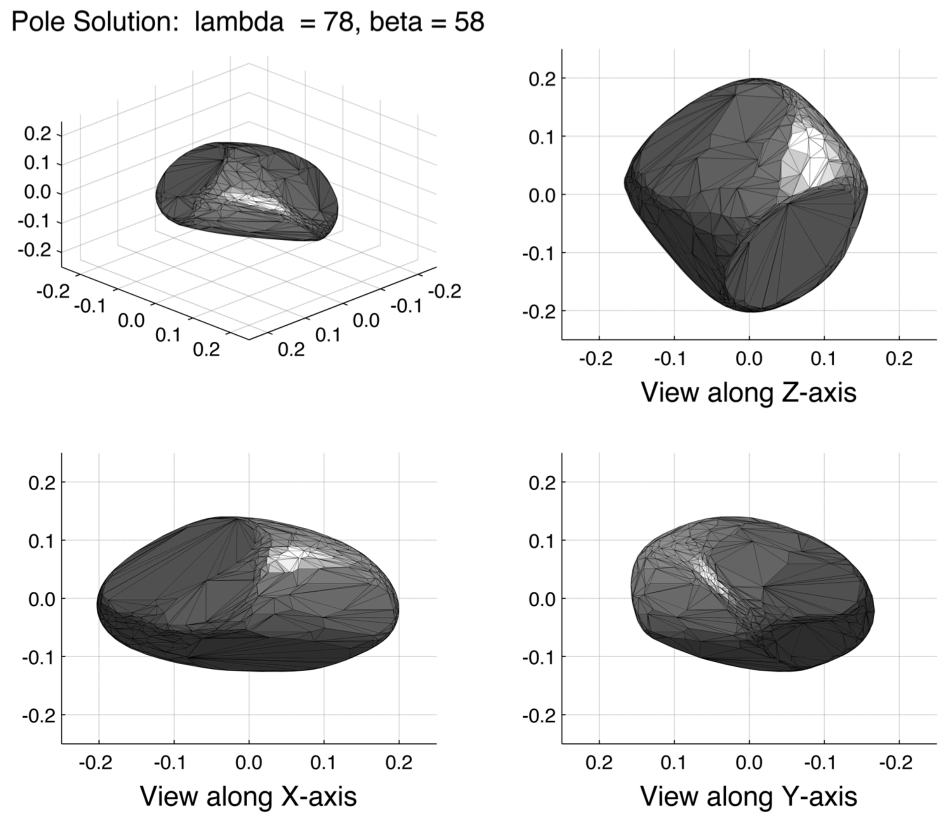
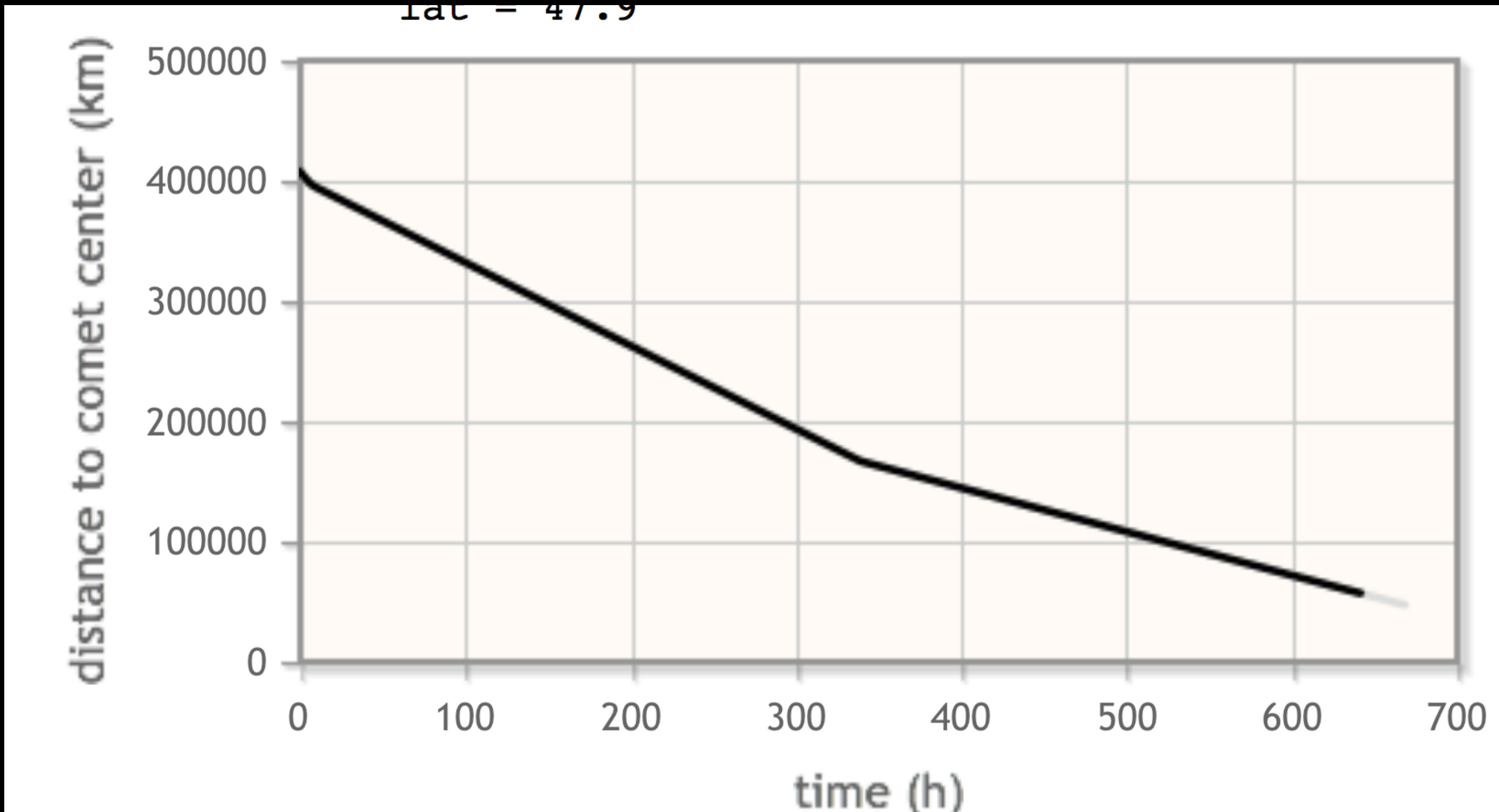


Fig. 5. Best-fit convex triangular-facet shape model produced via lightcurve inversion using the measured sidereal rotation period of 12.76137 hours and the most likely pole orientation, λ =78° and β =+58°. Axial ratios are well constrained at b/a = 1.239 and c/a = 0.819.

afstand van de komet in juni 2014

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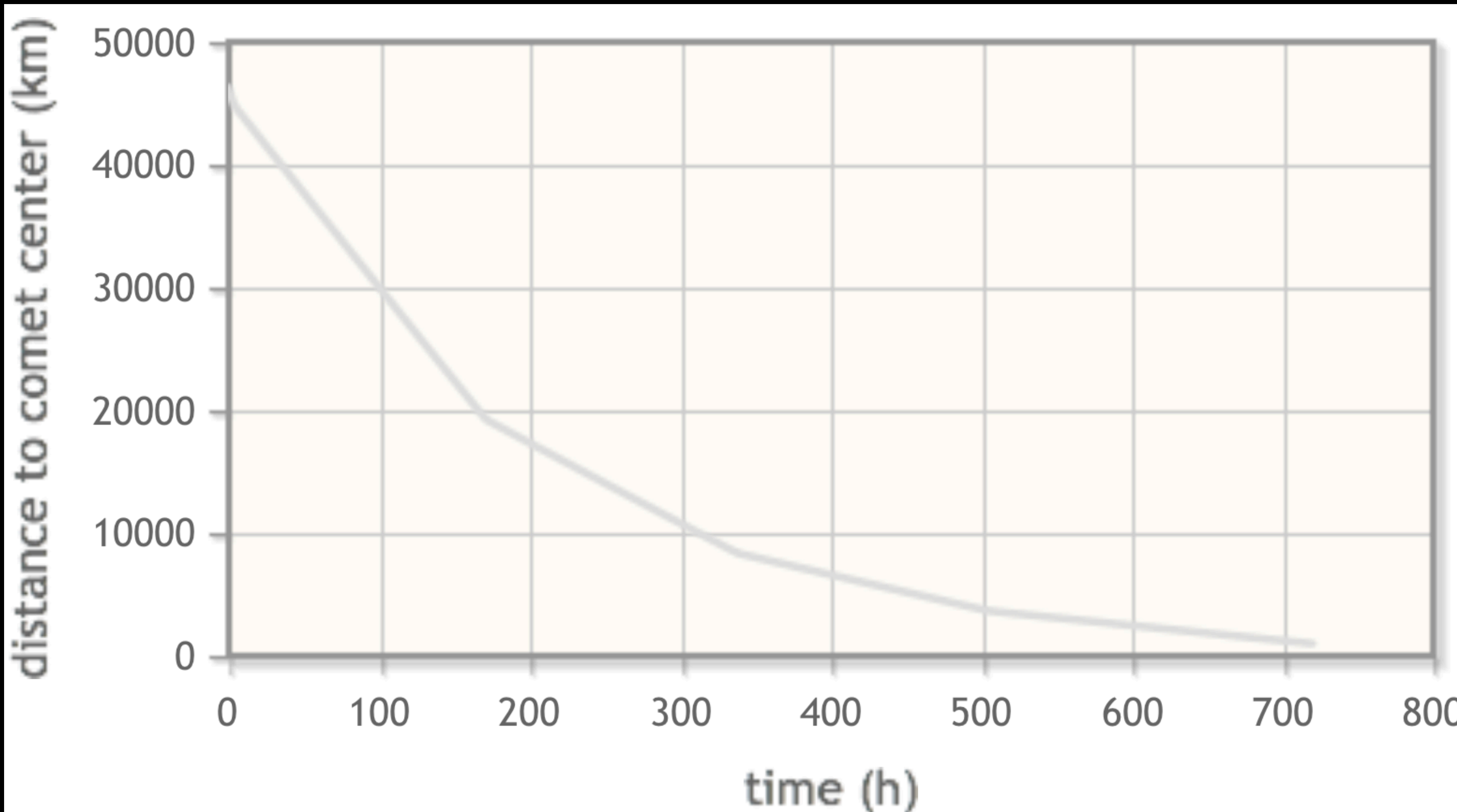
afstand van de komet in juli 2014



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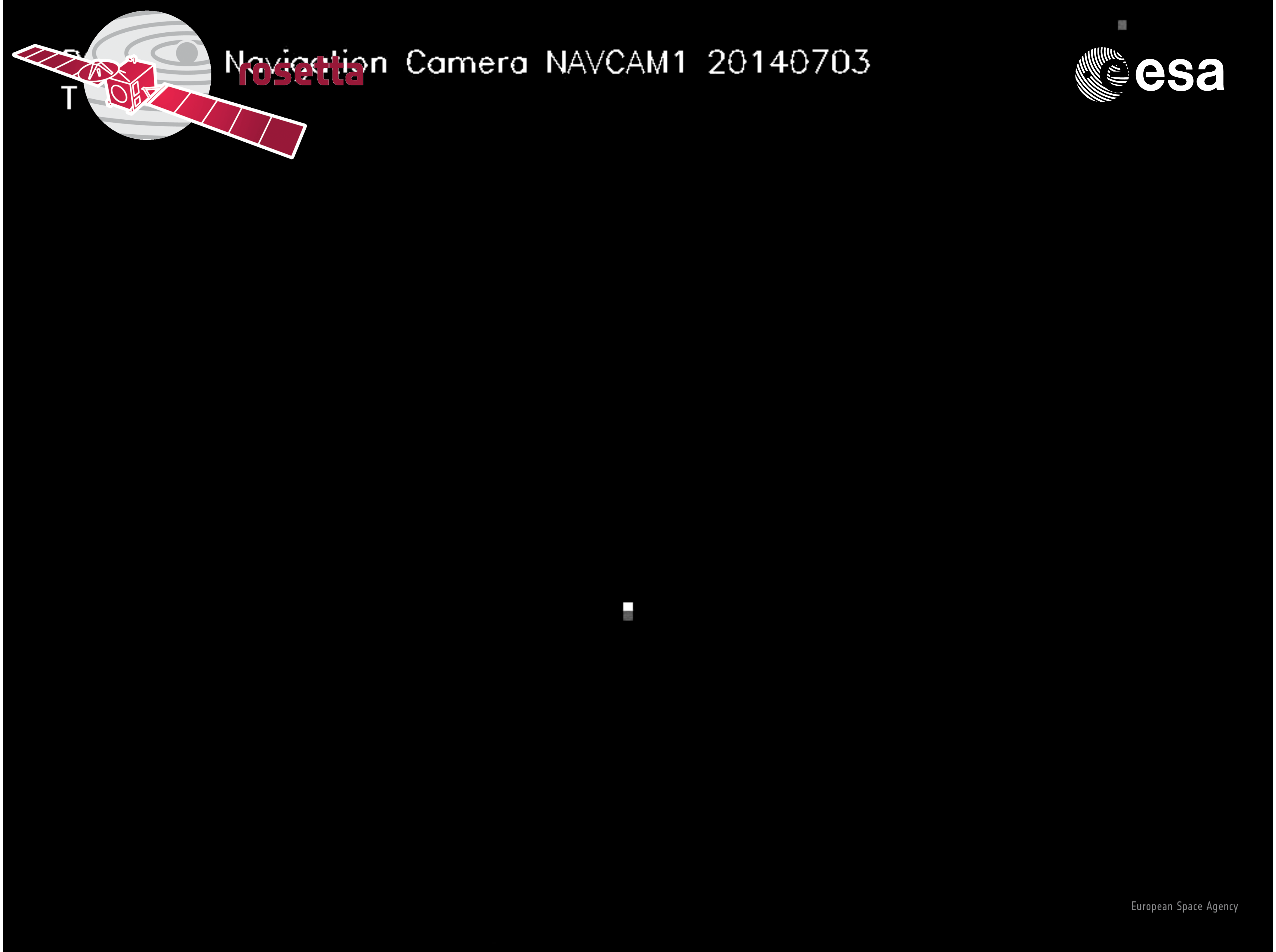
Navigation Camera NAVCAM1 20140703
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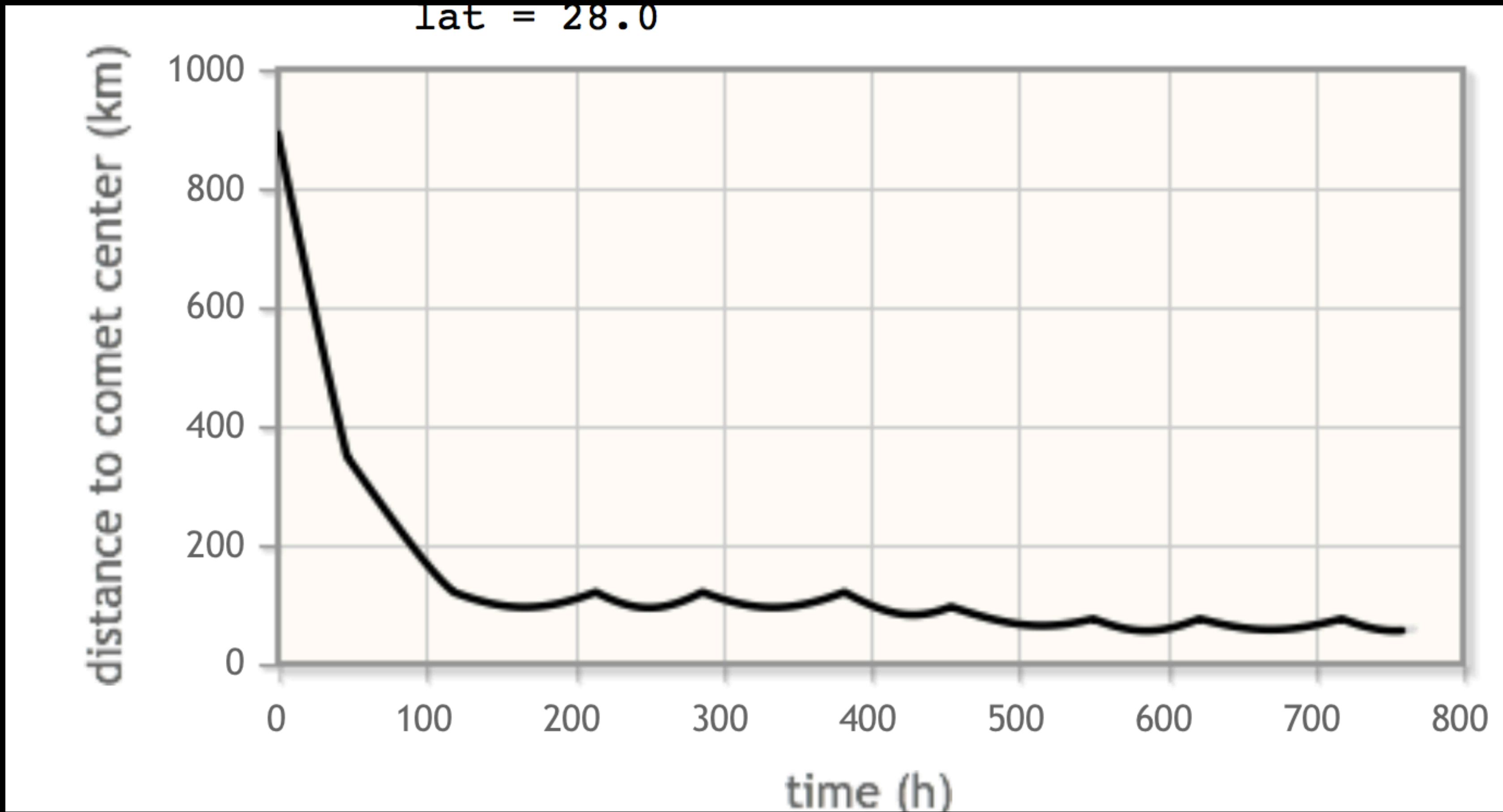
…

It was clear at the end of July 2014, that parameters and models needed adaptations and additional validation …

… but we did not yet have the full knowledge … and decided to go on …

afstand van de komet in augustus 2014




Navigation Camera NAVCAM1 20140803
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... with limited information, we went into the landing site selection meeting on 4-5 August 2014 ...

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status eind augustus:

> Gaida detecteert de eerste stofdeeltje (1 augustus 2014)

> Pre-selectie van 10 landingsplaatsen (21 augustus 2014)

> komeet massa: oorspronkelijke raming: 3x10 ^ 12kg, nu 1x10 ^ 15kg

> Radius: oorspronkelijke raming: ~ 2.1 km, nu [0.6,2.8] km

> Dichtheid: 3 modellen werden gebruikt: 100/370/800 kg / m ^ 3

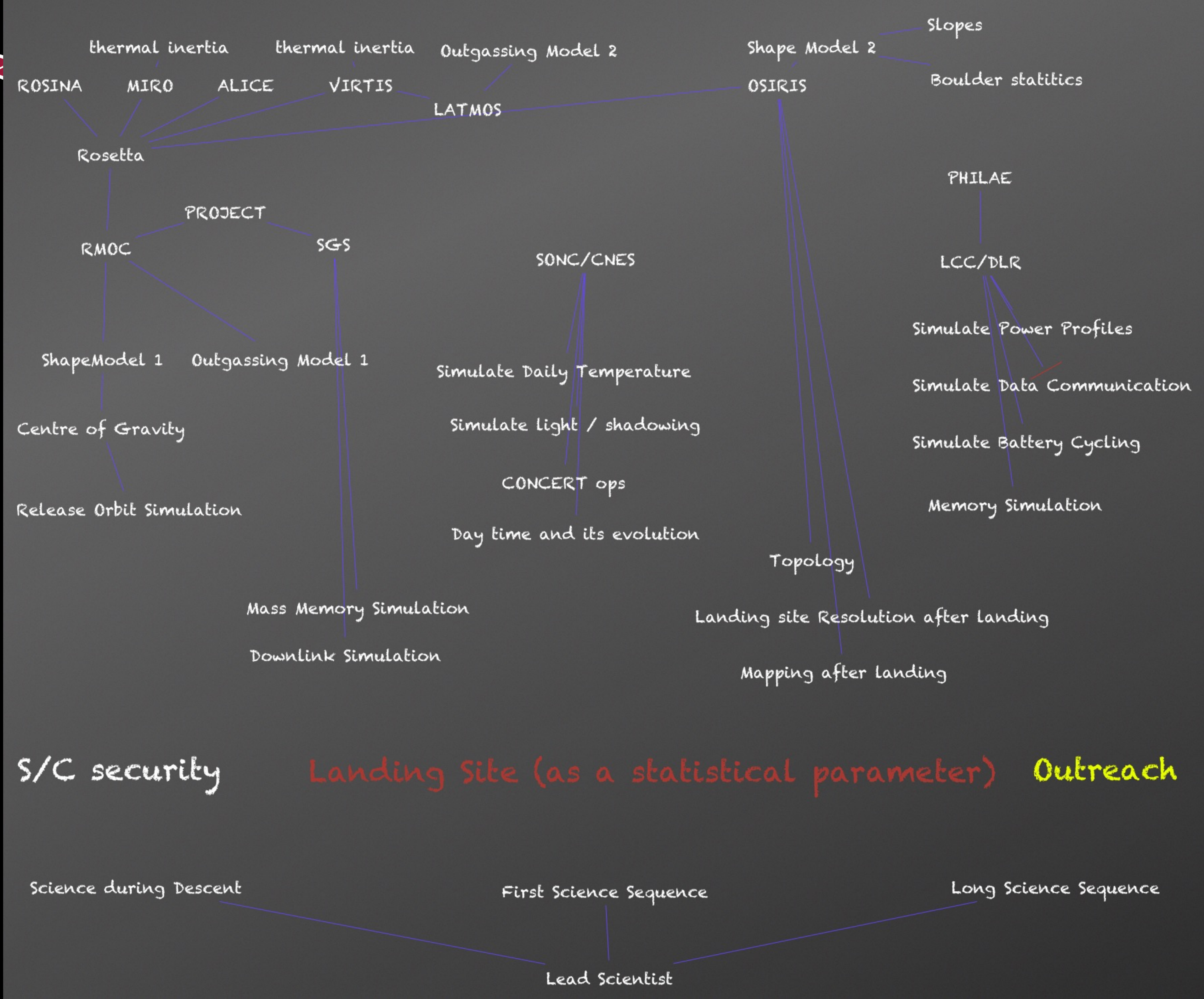
> Obliquity/schuinheid is constant: 53 graden -> CoG?

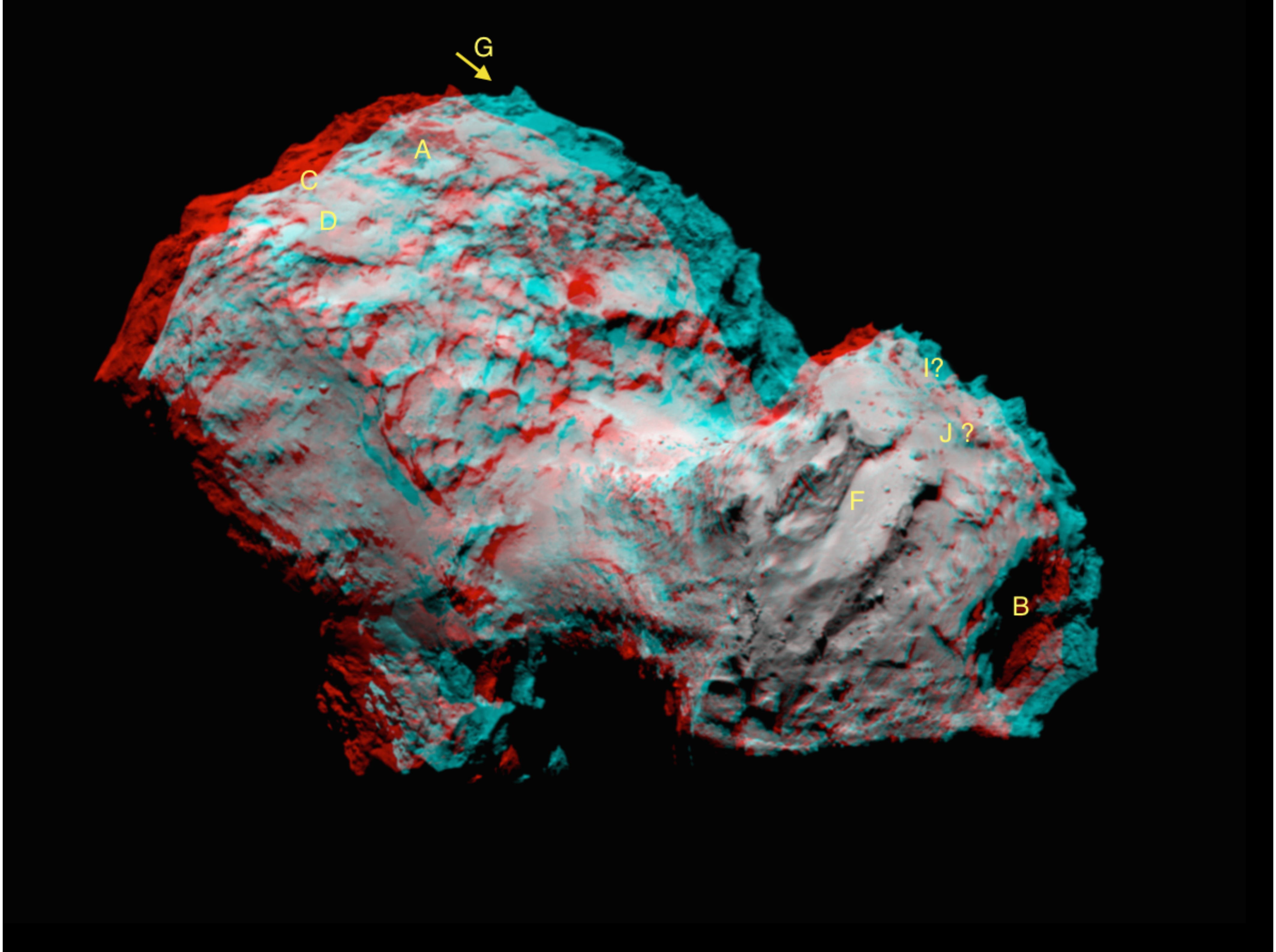
> CG buiten FOV van NavCam (22 augustus 2014)
Selectie van 5 landingsplaatsen (24 augustus 2014)

> Comet activiteit schatting en overeenstemming over wat er draait in LTP4 te vliegen (29 augustus 2014)

> Thermische kaart op komeet uit OSIRIS (29 augustus 2014)

Name	Site	Long. / Lat.	Illumination 11/11/14 (hrs)	Illumination 01/11/15 (hrs)	Landing Scenario	Dynamic Slope	Consert Color	Risk
LA_10	A	174 / 72	8.1	7.6	O1 – 6:30-8:30	15	Red	
In_Crater_2	B	353 / 5.2	6.4	6.3	O1 – 6:30-8:30	11	Green	
LA_16/HBO_4/ LA_12	C	205 / 26	7.6	7.2	O1 – 4:30-6:30	20	Yellow	
LA_14/HBO_3	D	134 / 45	10.3	9.1	O1 – 4:30-8:30	5	Yellow	Dispersion ellipse in two
LA_15/HBO_2	E	(78 / 24) 35 / [illegible]	11.4	9.5	O1 – 6:30-8:30	10	Green	
LA_17/HBO_5	F	318 / 22	9.7	8.8	O1 – 4:30-6:30	22	Yellow?	
LA_13	G	105 / 50	10.0	8.8	O1 – 6:30-8:30	20	Red	
Polar_Day	H	133 / 59**	12.48	12.48	None	15	None	
HBO_1	I	14 / 23	9.12	8.21	O1 – 4:30-6:30	10	Green	Dispersion ellipse in two
SFD_1	J	335 / 25				25		


thermal inertia
thermal inertia
Outgassing Model 2
Slopes
Shape Model 2
Boulder statitics
ROSINA
MIRO
ALICE
VIRTIS
LATMOS
OSIRIS
Rosetta
PHILAE
PROJECT
RMOC
SGS
SONC/CNES
LCC/DLR
Simulate Power Profiles
ShapeModel 1
Outgassing Model 1
Simulate Daily Temperature
Simulate Data Communication
Centre of Gravity
Simulate light / shadowing
Simulate Battery Cycling
CONCERT ops
Release Orbit Simulation
Memory Simulation
Day time and its evolution
Topology
Mass Memory Simulation
Landing site Resolution after landing
Downlink Simulation
Mapping after landing
S/C security
Landing Site (as a statistical parameter)
Outreach
Science during Descent
First Science Sequence
Long Science Sequence
Lead Scientist


G
A
C
D
I?
J ?
F
B

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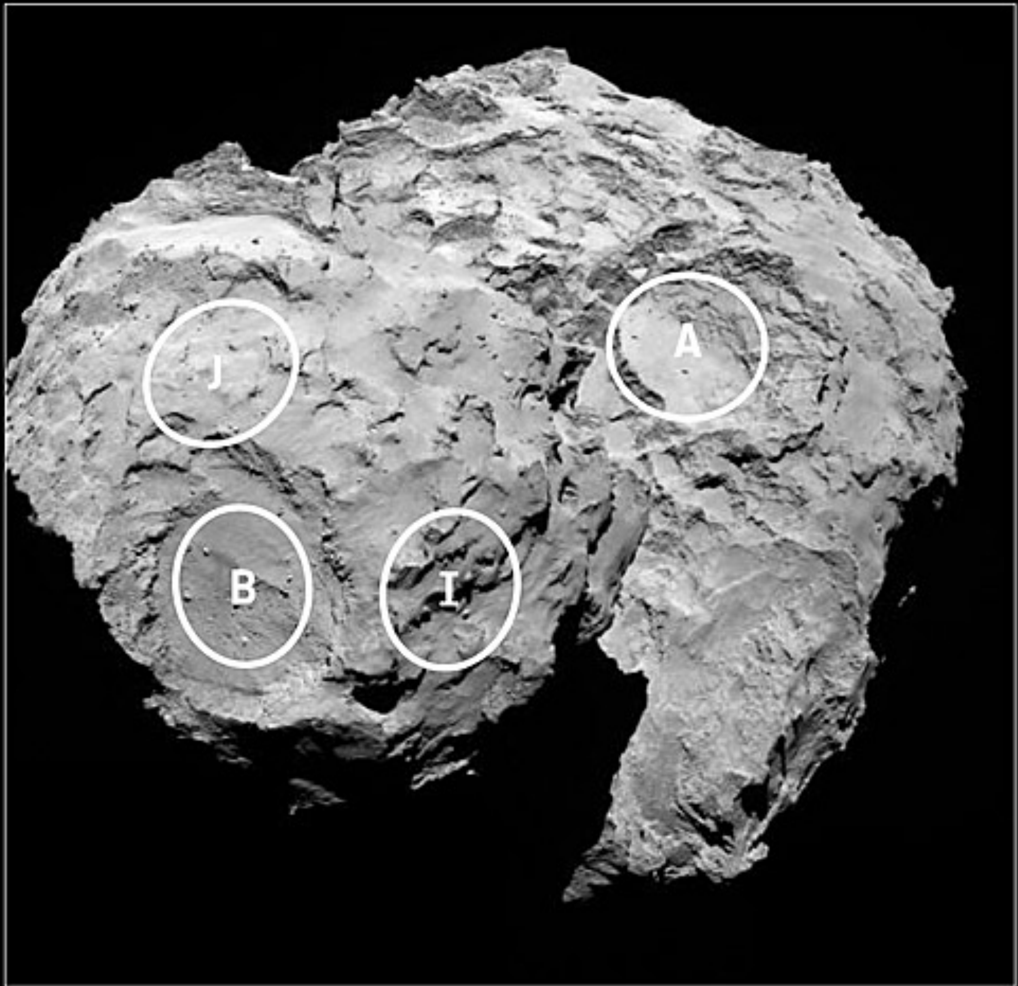
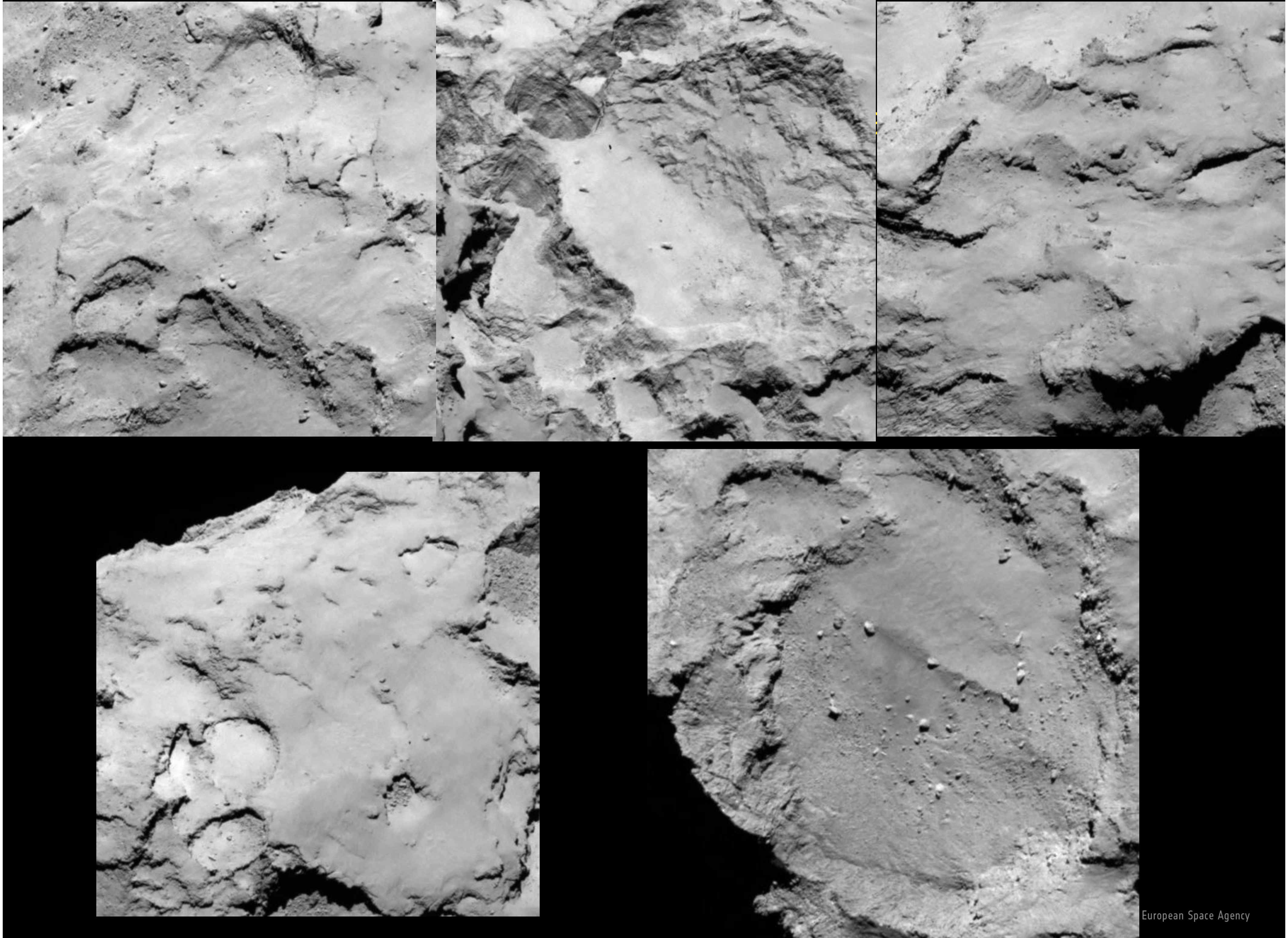
the selected landing spots from 5 August 2014





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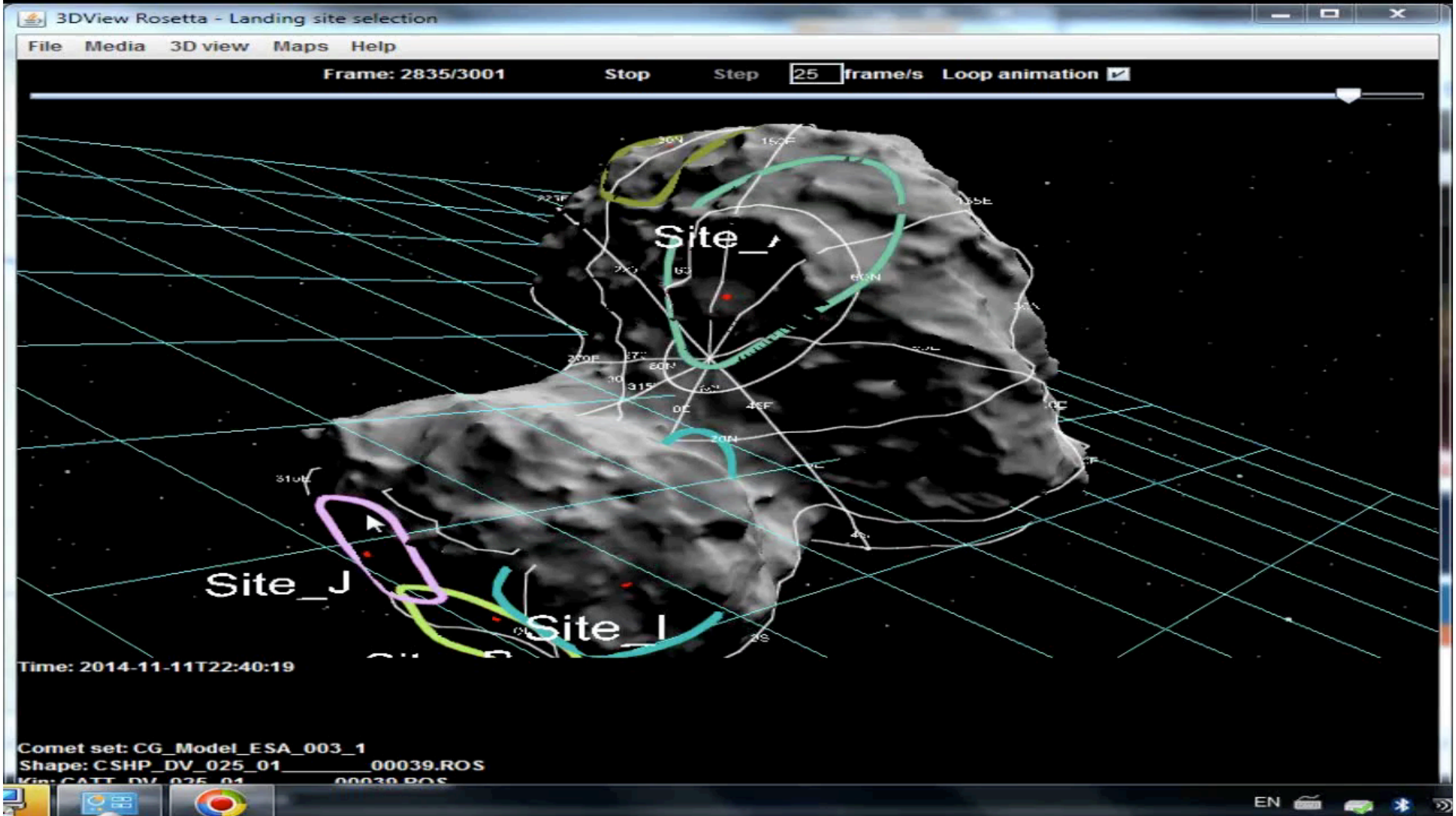
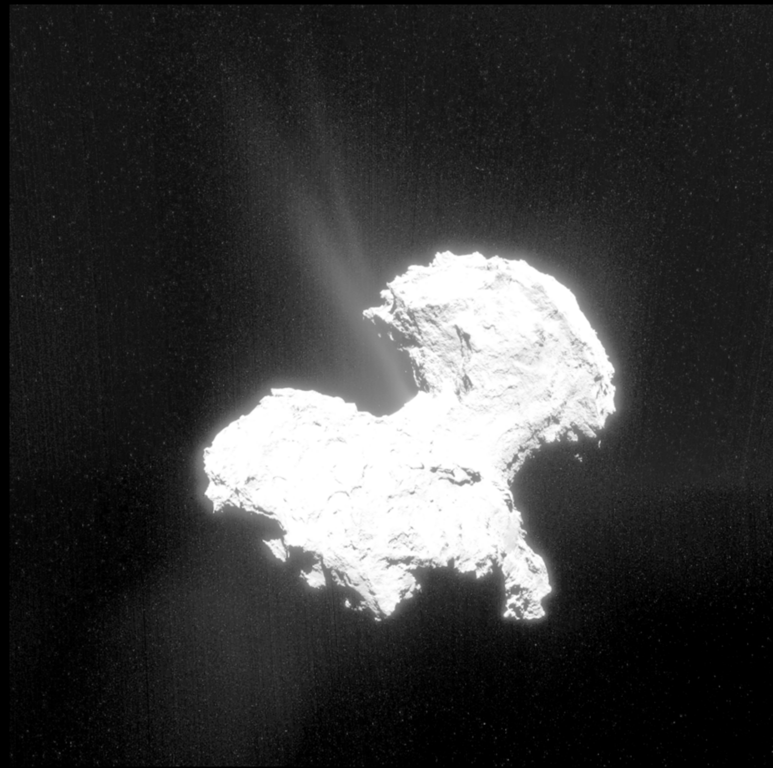

3DView Rosetta - Landing site selection
File Media 3D view Maps Help
Frame: 2835/3001
Stop
Step
25 frame/s
Loop animation
Site_A
Site_J
Site_I
Time: 2014-11-11T22:40:19
Comet set: CG_Model_ESA_003_1
Shape: CSHP_DV_025_01________00039.ROS
EN

rosetta

3 september 2014

esa



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from M. Malmer

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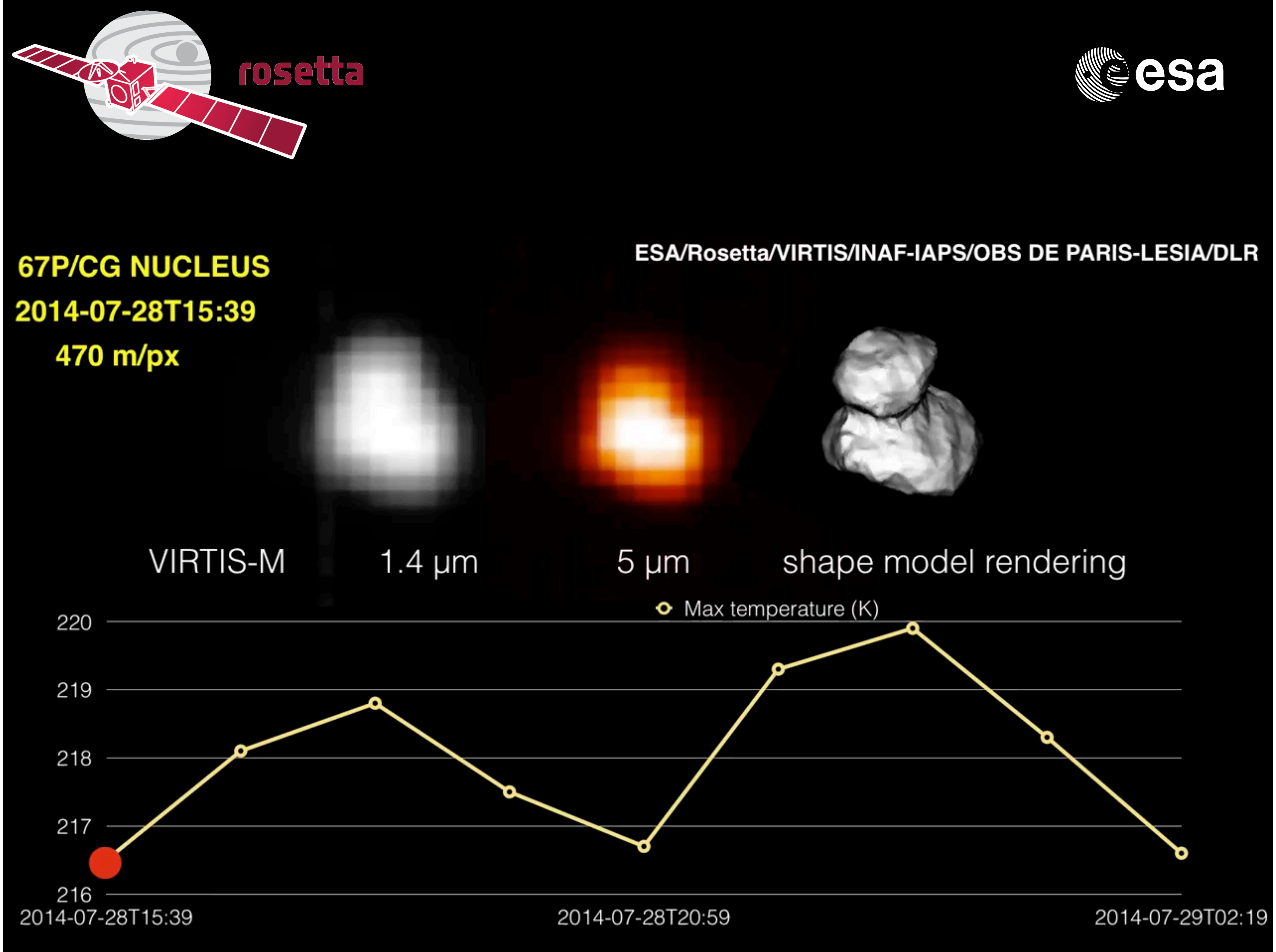
rosetta
esa
67P/CG NUCLEUS
2014-07-28T15:39
470 m/px
ESA/Rosetta/VIRTIS/INAF-IAPS/OBS DE PARIS-LESIA/DLR
VIRTIS-M
1.4 µm
5 µm
shape model rendering
Max temperature (K)
220
219
218
217
216
2014-07-28T15:39
2014-07-28T20:59
2014-07-29T02:19

Selection of prime landing site on the week-end of 13/14 September 2014 (see ON_LSSP2 meeting organization_Draft_270814)

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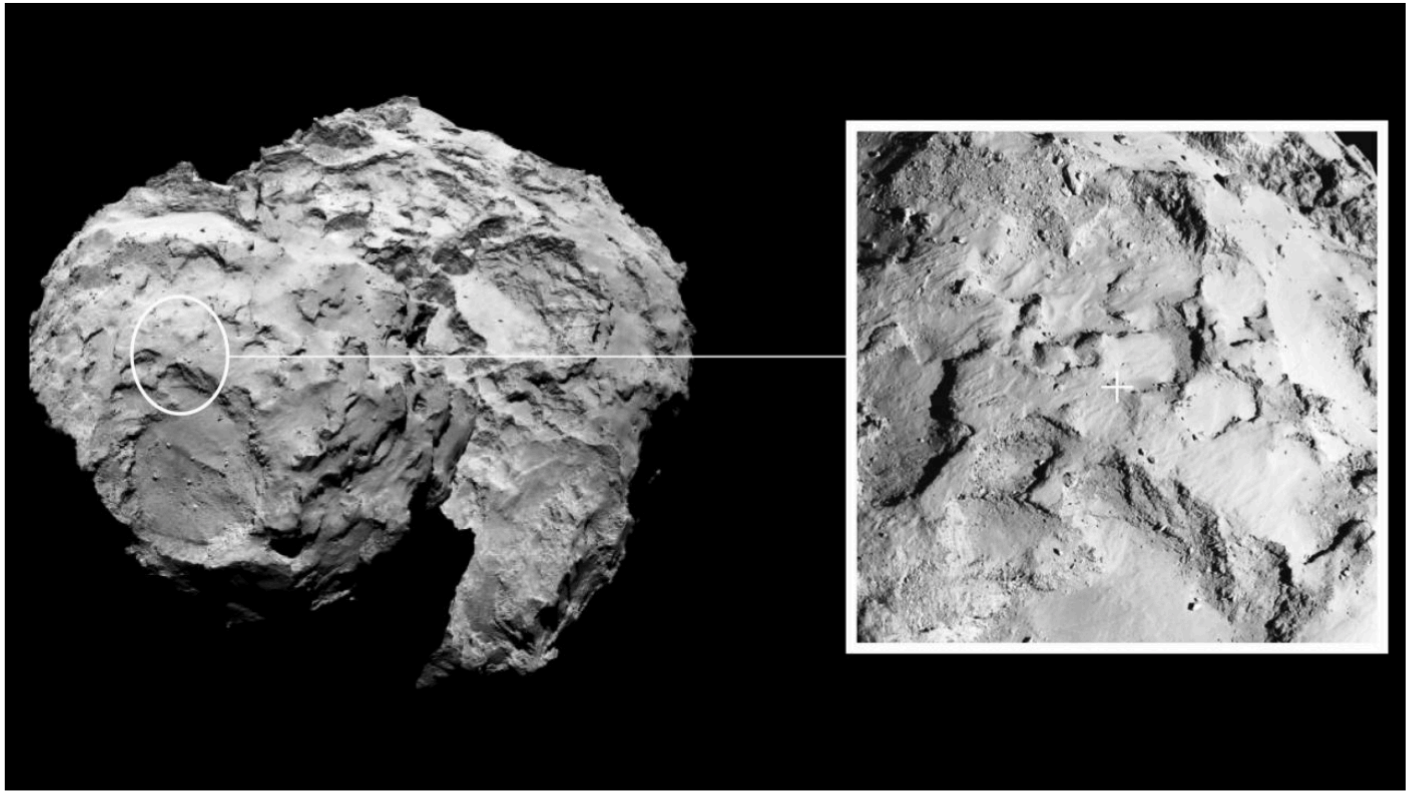
SHARE



Circle marks landing spot: Lander hopes to avoid jets of gas and dust that could complicate descent.

ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

Comet landing site picked: Rosetta to aim for the J spot

By **Eric Hand** | Sep. 15, 2014 , 8:15 AM

European Space Agency

rosetta

esa

10 November 2017: GO/NOGO

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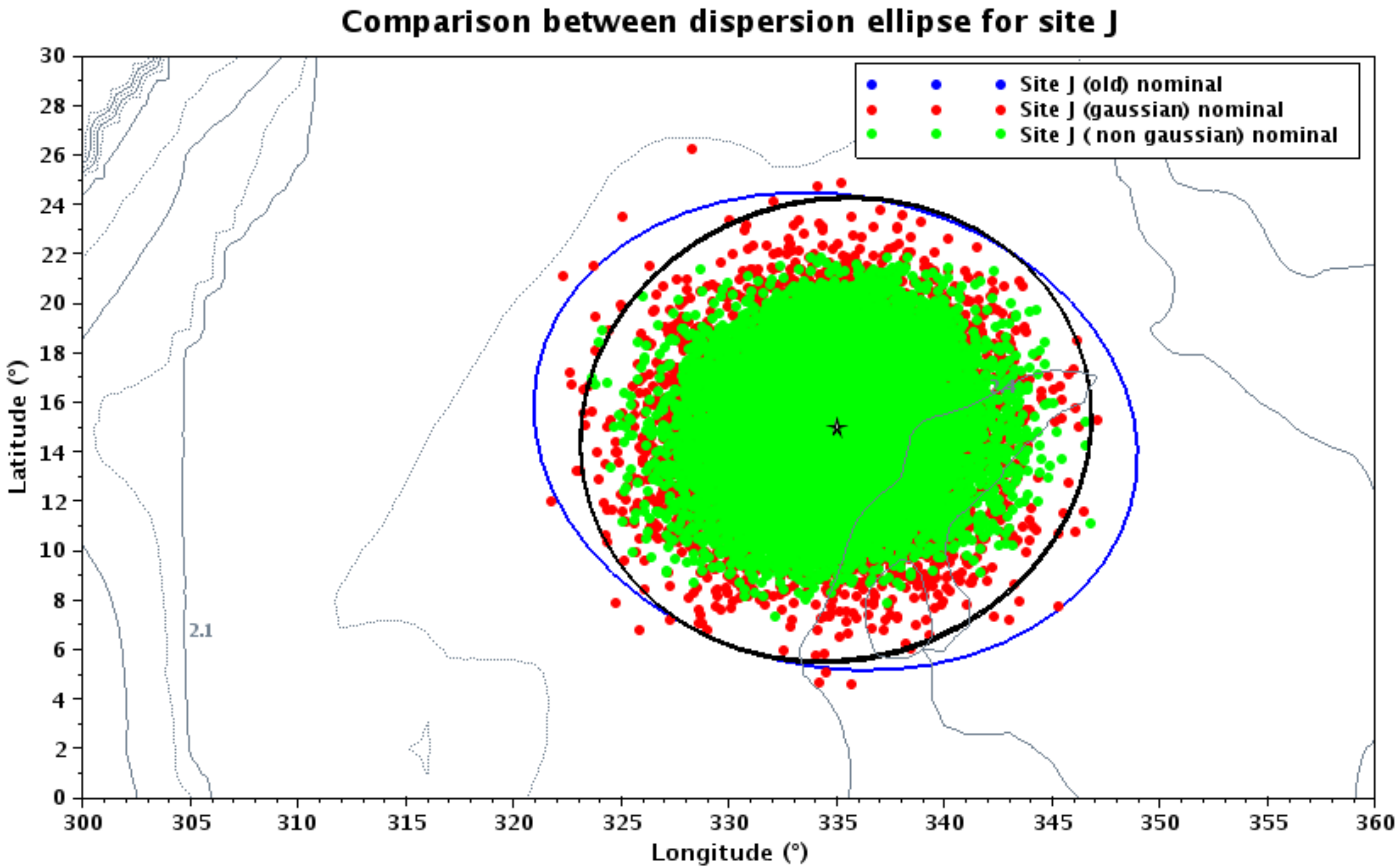
MEMO

Date	09/10/2014	**Ref**	RO-ESC-ME-5508
From	C. Casas	**Visa**	
To	S. Ulamec, J. Biele, B. Paetz, M. Maibaum, K. Geurts, C. Fantinati, P. Gaudon, E. Jurado, C. Delmas, A. Blazquez (RLGS)	**Copy**	M. Ashman (RSGS); J. Fertig, V. Companys, R. Guilanya, R. Bauske, A. Accomazzo, S. Lodiot, A. Hubault, R. Kay (RMOC);

Subject: Assessment of prediction error for lander delivery

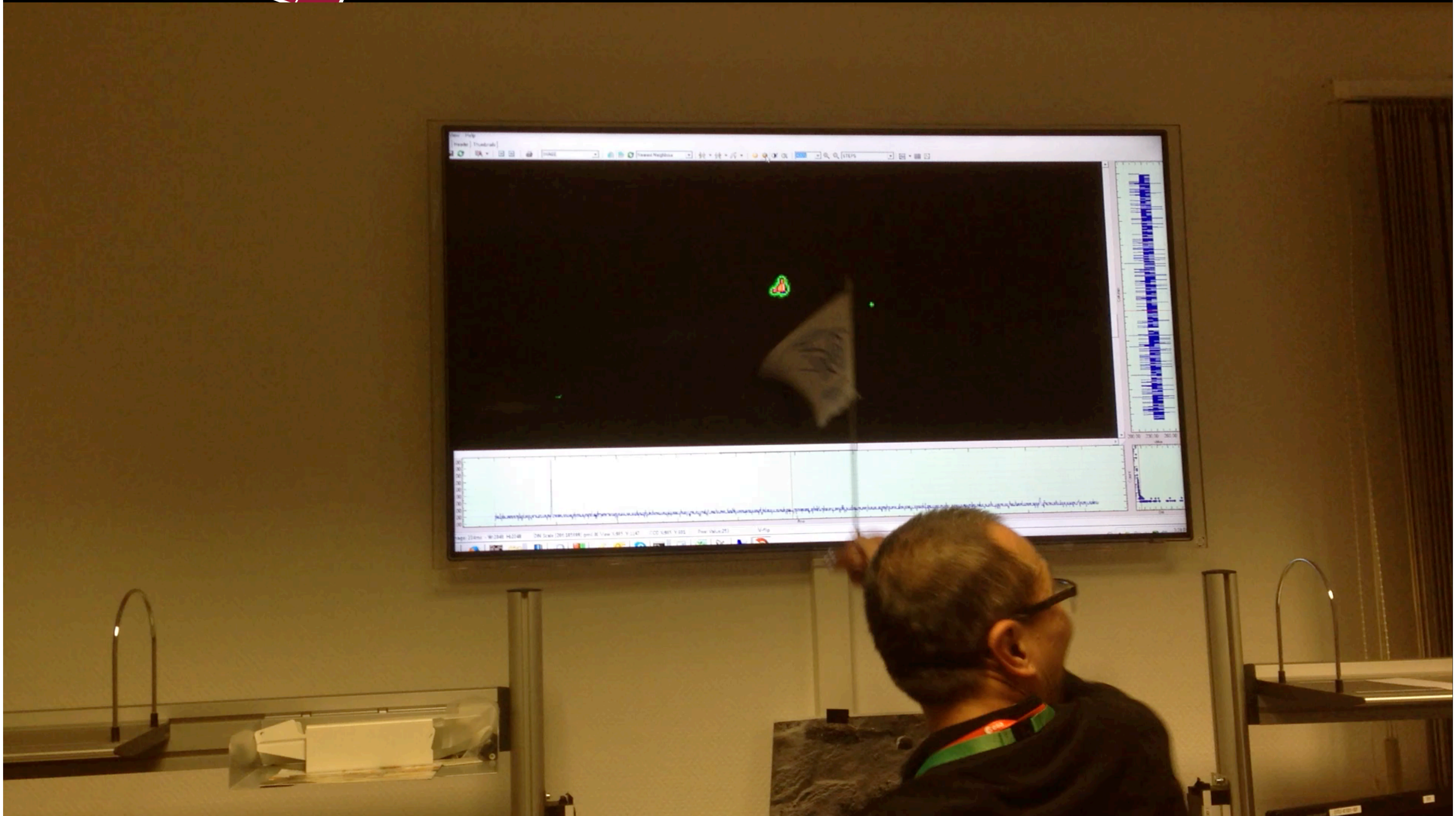
The navigation errors during the delivery sequence for both the orbiter and the lander for both site J (nominal) with strategy O1 and C (backup) with strategy O2 have been assessed as part of the LSSP-2 activity. The main results are specified in the LAFR delivered together with the LSSP-2 operational products. This memo shows results that have been requested by SONC but are not contained in the operational products.

The maximum expected navigation errors right before the pre-delivery manoeuvre for site J with strategy O1 (at a 30x30km orbit) are:


Comparison between dispersion ellipse for site J
Site J (old) nominal
Site J (gaussian) nominal
Site J (non gaussian) nominal
Latitude (°)
Longitude (°)
2.1
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
300
305
310
315
320
325
330
335
340
345
350
355
360

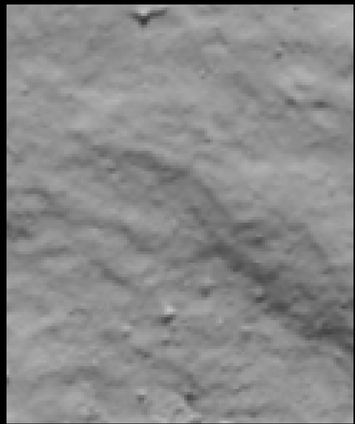
- show LSSP-3_System_Report_L32_10102014

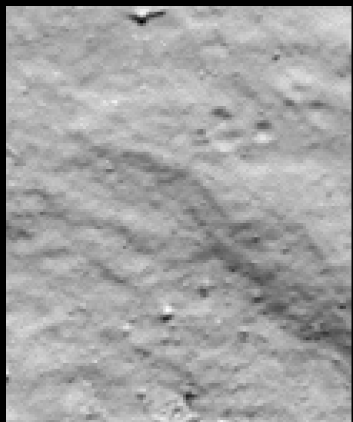
Philae Landing



Philae Landing

before





after

difference

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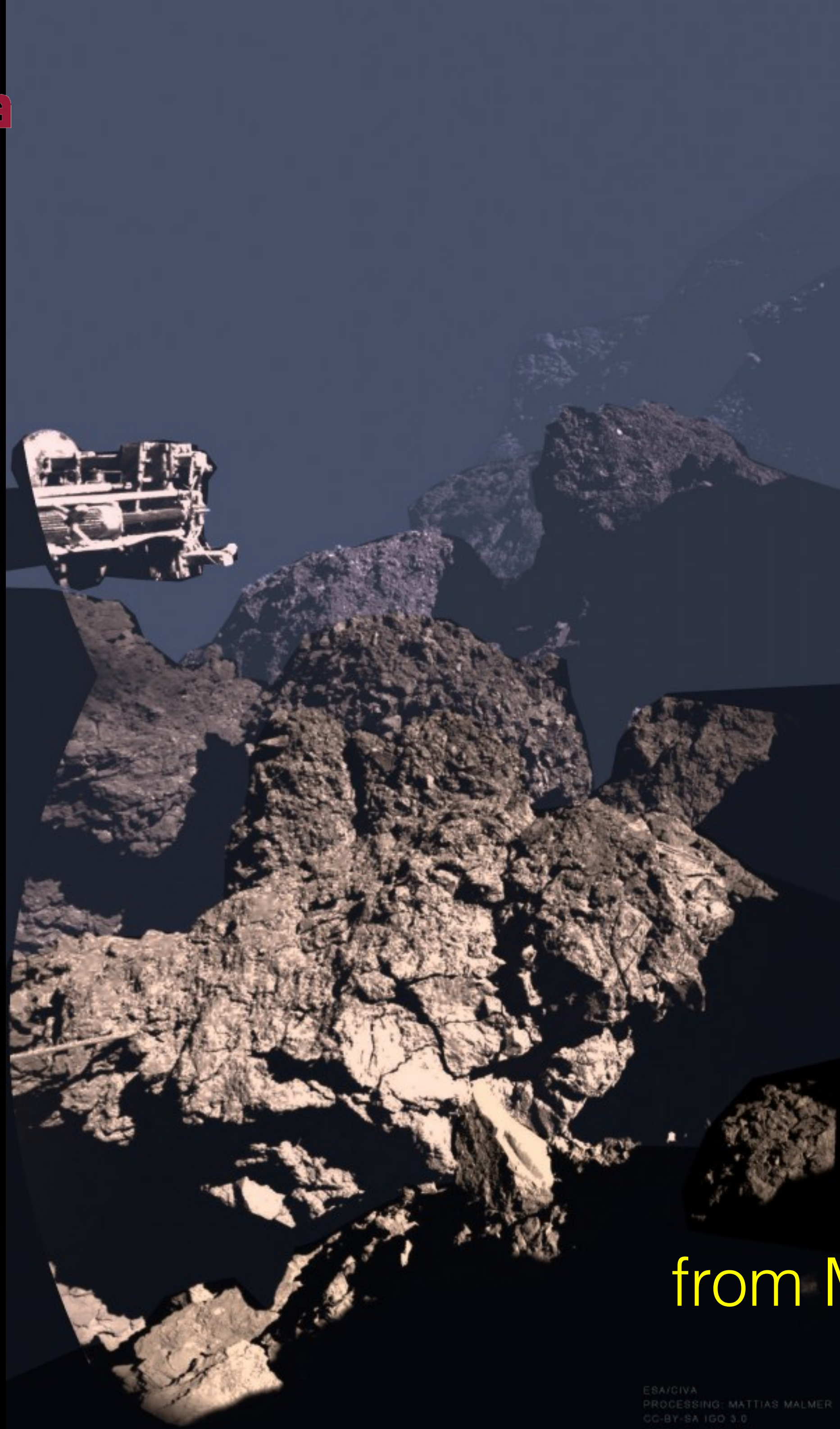
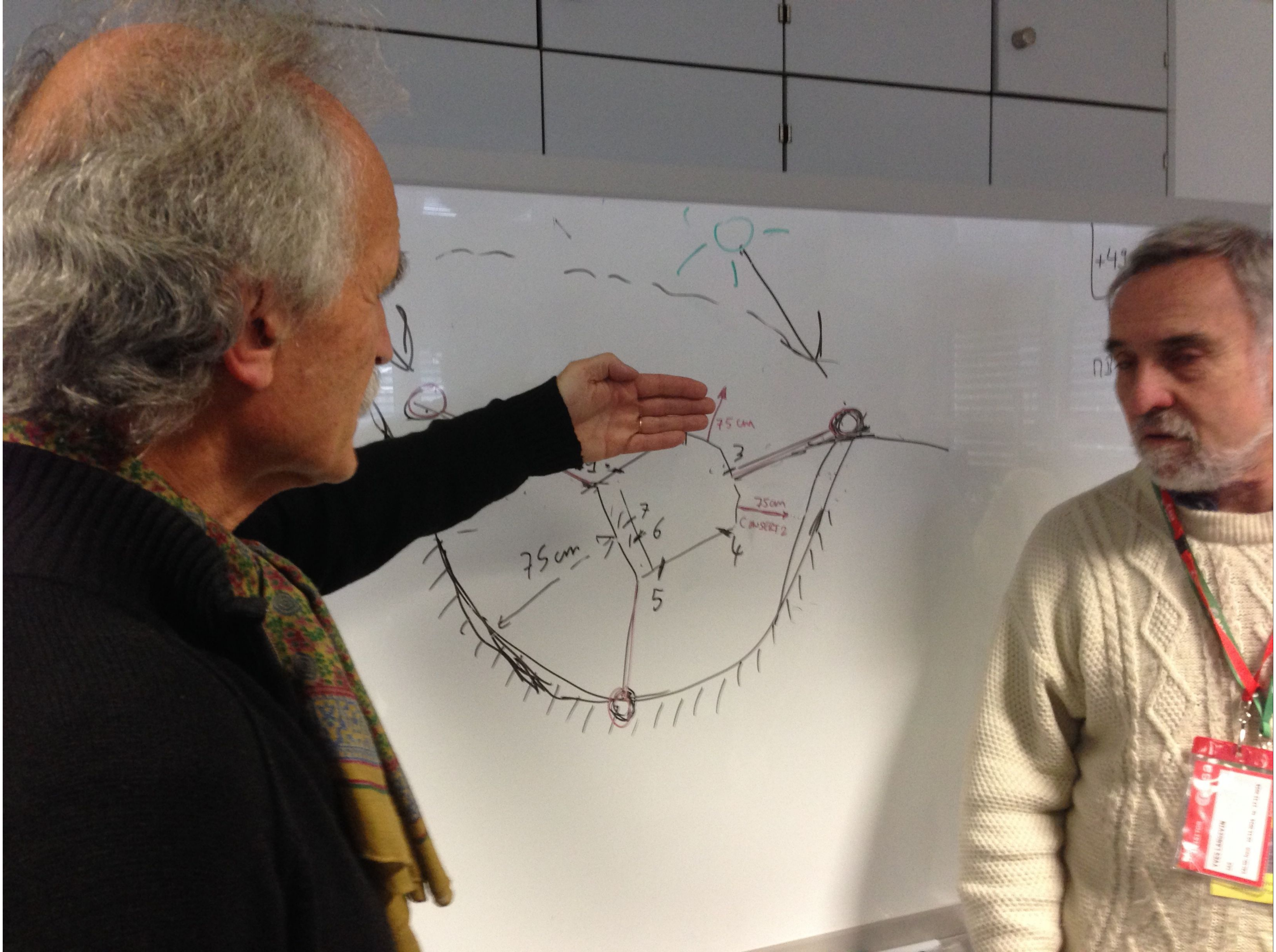


from M. Malmer



75 cm
3
75cm
4
75 cm
7
6
5