SDT meeting #10

JPL, Pasadena
February 4, 2014

Goals and Agenda
Louise Prockter

Meeting Goal

Develop recommendations on how to incorporate the recent candidate plume discovery into Europa Clipper science requirements and mission design

Agenda (a.m.)

8:30 Introductions, ICEE team member discussion, meeting goals (Prockter)

Project and sponsor overviews

8:45 NASA HQ update (Niebur/Salute)
9:00 Project Scientist update (Pappalardo)
9:15 Project Manager update (Goldstein)

Recent Europa science developments

9:30 Europa clay minerals (Shirley)
9:40 Europa plumes observations (Retherford)
10:00 Europa plate tectonics (Prockter)

10:10 Break

Science discussions

10:30 Science Traceability Matrix discussion (All)

- Traceability Matrix status recap and open issues (Senske)
- Should plumes be part of C1, or should they have their own investigation?
- If the latter, what would that look like?
- Do other investigations (ice shell, geology) need modification?
- How might a plume discovery affect the Recon plan?

12:15 Lunch

Agenda (p.m.)

Payload and trajectory

1:30 Payload (All)

- Is the current model payload sufficient to address the STM modifications? (Pappalardo)
- If additions are recommended, what compensating cuts are recommended?

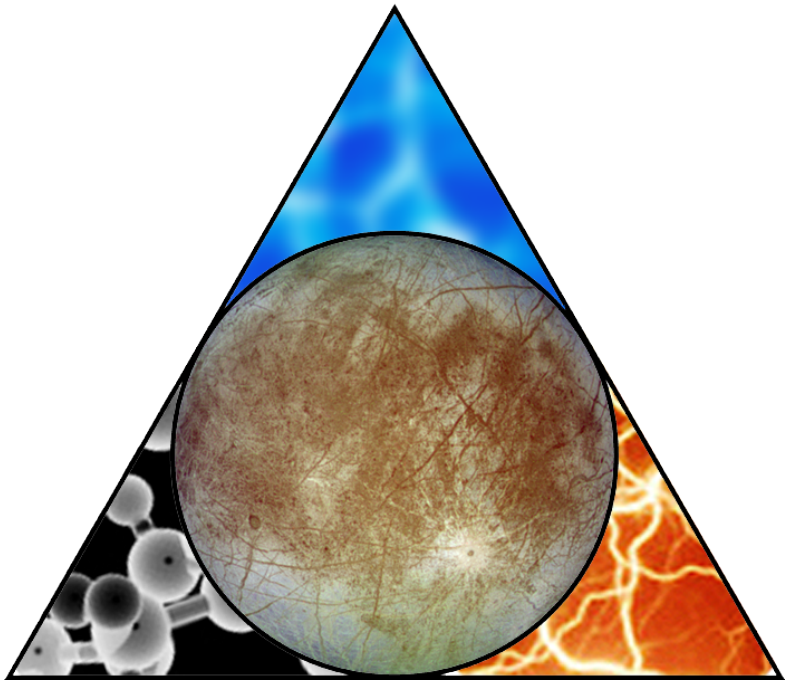
2:30 Mission design

- Plume observing scenarios with F-7 trajectory (Buffington)
- Recommended modifications to mission design to capture plume (All)

3:30 Break

Future actions

3:50 Recommended future plume studies to reduce uncertainties
4:00 Other issues
5:00 Next steps
5:30 Adjourn



Project Science Update

Robert Pappalardo[1], Louise Prockter[2], and Dave Senske[1]

[1]Jet Propulsion Laboratory, California Institute of Technology
[2]Applied Physics Laboratory, Johns Hopkins University

Europa Science Definition Team

- Recent presentations to SDT are publicly posted
  - http://solarsystem.nasa.gov/europa/technical.cfm
- ICEE conversations are managed
  - ICEE Science represented by R. Pappalardo and S. Vance

Europa Clipper Science Activities

- Organization of Workshop on the Habitability of Icy Worlds (Senske, Vance, Patterson)
- Trajectory Evaluation for Science (Prockter, Patterson, Craft, Vance)
- Science and Recon Requirements Definition (Paczkowski)
- Science Traceability Matrix Updates (Senske)
- Science Interactions with ICEE Teams (Pappalardo, Vance)
- Instrument Calibration Concepts (Paczkowski)
- SDT Interactions (Prockter, Senske)
  - Traceability corrections and updates
  - Clarifications for requirements definition
  - Implications of Europa plumes – telecon
  - Reconnaissance Working Group status – telecon
  - SDT meeting arrangements (Feb. 4, 2014)
  - Evaluation of SWIRS FOV

Europa Clipper Science Activities (cont.)

- Science Risk Reduction Tasks – Several Funded (Paczkowski, Pappalardo)
  - Langmuir Probe science study funded (Bagenal, Khurana, Jia, et al.)
  - Laser altimetry science study getting funded (Smith & Zuber)
  - Plume detection science study getting funded (Hurford & Rhoden)
- Science Communications (Phillips, Dyches, Vance)
  - Europa blog (solarsystem.nasa.gov/europa)
  - Images and graphics
  - Europa video support
  - Europa Science Series initiated
- Science Presentations (All)
  - OPAG, AGU, DPS, GSA, IAA, Icy Worlds Workshop (All)
  - Docushare presentation database (Patterson)
- Technical and Architecture support (Senske, Vance, Pappalardo)
  - Science Observation Strategy Concept (Senske)
  - Science Observation Scenarios (Paczkowski)
  - Science Concerns (Vance)
  - Science Stakeholders (Patterson)
  - Science Risk tracking (Senske)
  - Science Operations Center functions and flow, and lessons learned (Paczkowski)
  - Gravity Working group support (Paczkowski, Senske)

Science Risk Reduction Tasks

Proposals and Contracts in Work

- Plasma science feasibility (Bagenal, Cassidy, Dols, Khurana, Jia)
  - Can Langmuir probes enable plasma correction for magnetometry?
- Stereo-based topography modeling (Kirk, pending)
  - What are the implications of tour lighting and resolution on DEM topographic information?
- Implications for sounding interpretation (Heggy)
  - What are clutter removal implications of the expected DEM topographic data set?
- Opportunities for plume observations (Hurford, Rhoden)
  - What are the most promising imaging opportunities?
- Tidal amplitude for ocean science (Smith, Zuber, Mazarico, Genova)
  - Can laser altimetry achieve ocean science from multiple flybys?
- Implications of teaming styles for science style (Vertesi, pending)
  - How do science teaming arrangements best enable synergistic science?

Science study results to be publicly reported.

Science Evaluation of 13F7 Trajectory

- 13F7 trajectory is being analyzed to determine its ability to enable Science and Reconnaissance objectives
  - Each flyby is being analyzed against each measurement requirement
  - For remote sensing instruments, modeling of surface footprints is in progress

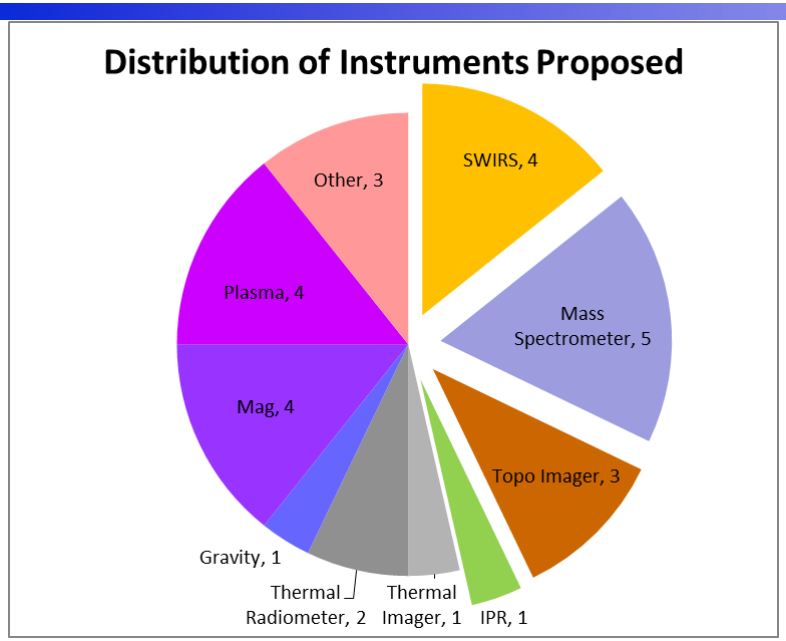
- Work is in progress
- Preliminarily, most of the “tall tent-pole” measurements can be achieved
- Thermal imaging both pre-dawn and mid-day is the most challenging

Flyby Number	IPR		SWIRS		TI	NMS	RC	MAG	LP	RS	ThI
1	0	0	0	7	0	752.7	752.7	122	9:18:18	0.196	
	0	0	2	7	0	250	250	128	11:20:24	0.196	
	0	0	4	7	0	100	100	138	11:03:08	0.195	
	0	0	4	7	0	100	100	149	10:58:22	0.189	
	0	0	4	7	0	50	50	161	10:50:46	0.186	
	0	0	7	7	0	25	25	172	10:23:32	0.184	
	0	0	7	7	0	100	100	-177	8:09:09	0.183	
	0	0	7	7	1	100	100	-138	7:50:18	0.181	
	0	0	7	7	2,3	25	25	-126	11:42:12	0.169	
10	0	0	7	7	4	50	50	-113	8:23:58	0.139	
	0	0	7	7	5	25	25	-102	8:49:19	0.101	
	0	0	7	7	6,7	50	50	-93	8:53:03	0.101	
	0	0	7	7	7	25	25	-83	8:54:03	0.089	
	0	0	7	7	7	565.2	565.2	-71	19:48:53	0.085	
	0	0	7	9	7	1872.2	1872.2	-29	19:54:20	0.085	
	0	0	7	9	7	2710.3	2710.3	-36	17:19:16	0.085	
	0	0	7	10	7	50	50	11	19:22:32	0.062	
	0	0	7	10	7	50	50	5	18:33:25	0.056	
	0	0	7	10	7	81.2	81.2	47	20:31:08	0.044	
20	0	0	7	10	7	50	50	43	19:23:51	0.033	
	0	0	7	10	7	100	100	89	21:22:34	0.026	
	0	0	7	10	7	50	50	79	20:14:48	0.026	
	0	0	7	10	7	50	50	127	22:10:38	0.021	
	0	0	7	10	7	100	100	121	21:01:52	0.02	
	0	0	8	11	7	50	50	165	23:12:18	0.02	
	0	0	8	11	7	50	50	175	21:56:45	0.019	
	0	0	8	11	7	50	50	-175	21:55:28	0.019	
	0	1	8	11	8	25	25	-157	22:05:58	0.019	
	0	1	9	14	8	546.7	546.7	116	22:10:28	0.019	
30	0	1	9	14	8	1009	1009	-169	14:30:52	0.019	
	0	2	11	14	9	100	100	167	2:21:39	0.019	
	0	2	12	14	9	100	100	180	13:01:01	0.019	
	0	2	13	14	9	50	50	-168	13:43:55	0.019	
	0	3	14	14	10	50	50	-157	13:44:33	0.019	
	0	3	14	14	10	25	25	-147	13:14:42	0.019	
	0	4	14	14	11	303.4	303.4	-140	13:58:44	0.019	
	1,2	5	14	14	12	50	50	-155	14:53:20	0.018	
	3	5	14	14	12	25	25	-137	17:39:57	0.018	
	3	6	14	14	13	50	50	-130	15:44:50	0.018	
40	4,5,6	7	14	14	14	25	25	-108	17:05:41	0.018	
	6	7	14	14	14	50	50	-104	15:50:52	0.018	
	6	7	14	14	14	50	50	-85	15:47:27	0.018	
	7	7	14	14	14	25	25	-81	15:05:11	0.017	
	7	7	14	14	14	50	50	-61	14:00:08	0.017	
	7	7	14	14	14	25	25	-57	4:11:20	0.016	

“tall pole” progress | floor fulfilled | baseline fulfilled

ICEE: Submission Statistics and Selections

From Curt Niebur



Instrument Type	# Props	# Selections
SWIRS	4	3
Mass Spectrmtr	5	3
Topo Imager	3	2
IPR	1	1
Thermal	3	2
Gravity	1	0
Magnetometry	4	2
Plasma	4	1
Other	3	1
Total	**28**	**15**

PI	Inst	Title	Instrument Type
Bell, James	ASU	Topographic Imager Technology Development	Topo Imager
Turtle, Elizabeth	APL	Topographic and Reconnaissance Imaging for Europa Exploration	Topo Imager
Aslam, Shahid	GSFC	Thermal IMager for Europa Reconnaissance (TIMER) - "Tech Maturation and Risk Mitigation"	Thermal Imager
Kenyon, Matt	JPL	Thermal Radiometer Development for Europa Clipper mission	Thermal Rad
Smith, David	MIT	Extended Range Laser Altimeter (ERLA)	Laser Altimeter
Westlake, Joseph	APL	Plasma Instrument for Magnetic Sounding (PIMS)	Faraday Cup
Bagenal, Frances	Univ. CO	Colorado Europa Langmuir Probe	Langmuir Probe
Raymond, Carol	JPL	Vector/Scalar Magnetometer for Europa Clipper	Magnetometer
Moussessian, Alina	JPL	Ice Penetrating Radar for Europa Exploration	Radar
Kempf, Sascha	Univ. CO	Maturing the Surface Dust Analyzer (SUDA) for Europa Exploration	Dust Analyzer
Waite, Jack	SWRI	MASPEX-ICEE	Mass Spectrometer
Green, Robert	JPL	ESWIRS-RPM	SWIRS
Reuter, Dennis	GSFC	SIRSE: Spectral ImageR/ Spectrometer for Europa	SWIRS
Hand, Kevin	JPL	CIRIS SWIR/MIR spectrometer for Europa Clipper	SWIRS
Darrach, Murray	JPL	Mass Analyzer for Real-time Investigation of Neutrals at Europa (MARINE)	NMS

ICEE Collaborations

- A “welcome” briefing to all ICEE teams was held by the Pre-Project Team on October 23, 2013
- A public website was established as a repository for general information that may be helpful to the ICEE teams and other potential instrument providers
  - Welcome briefing charts, science and reconnaissance trace matrices, 13-F7 trajectory files, and a 3D spacecraft model are posted:

    http://solarsystem.nasa.gov/europa/technical.cfm
- Fruitful follow-up interactions
  - ICEE teams have shared useful information related to their instrument interfaces, required resources, calibration requirements, and special considerations such as EMI/EMC and spacecraft outgassing
  - This has been beneficial in validating the project design

Model Payload Prioritization by SDT

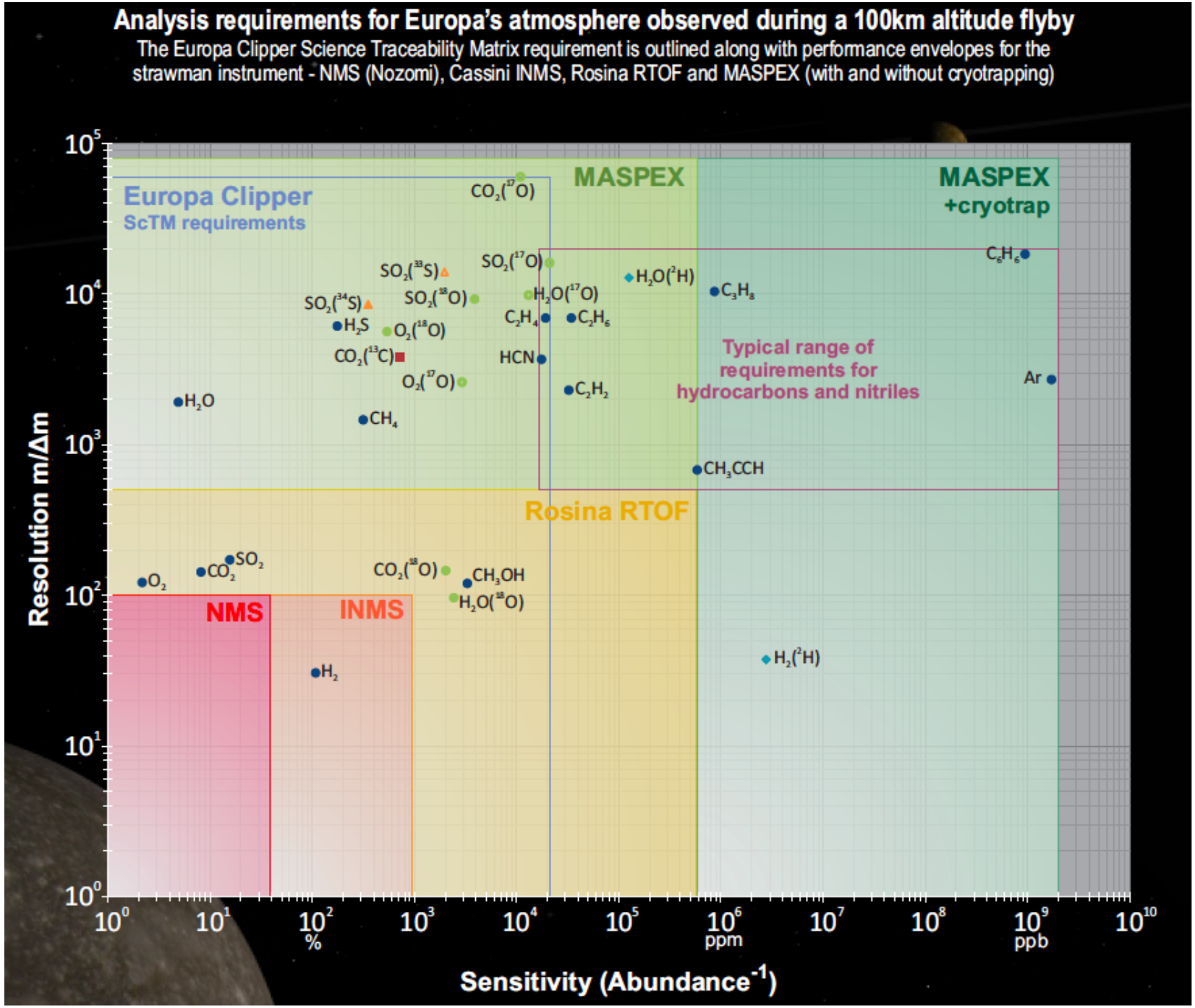
Dec. 2012 Report

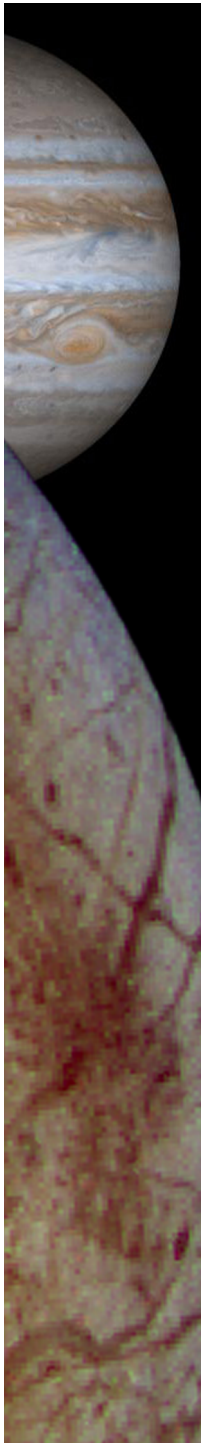
SCIENCE

- Floor Model Payload for Science (no relative priority)
  - Ice-Penetrating Radar
  - ShortWave Infra-Red Spectrometer
  - Topographical Imager
- Baseline Model Payload for Science (prioritized, highest to lowest)
  - Neutral Mass Spectrometer
  - Magnetometer + Langmuir Probes
  - Gravity Science
- Additional mission capability descopes exist
  - See Science and Recon Traceability Matrices

RECON

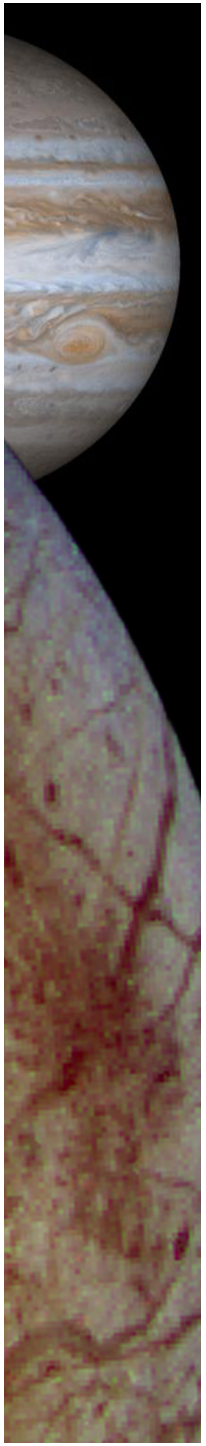
- Baseline Model Payload for Recon (prioritized, higher to lower)
  - Recon Camera
  - Thermal Imager


Analysis requirements for Europa's atmosphere observed during a 100km altitude flyby
The Europa Clipper Science Traceability Matrix requirement is outlined along with performance envelopes for the strawman instrument - NMS (Nozomi), Cassini INMS, Rosina RTOF and MASPEX (with and without cryotrapping)
Europa Clipper
ScTM requirements
MASPEX
MASPEX
+cryotrap
Typical range of requirements for hydrocarbons and nitriles
Rosina RTOF
NMS
INMS
$CO_2(^{17}O)$
$SO_2(^{33}S)$
$SO_2(^{17}O)$
$SO_2(^{34}S)$
$SO_2(^{18}O)$
$H_2O(^{17}O)$
$H_2O(^2H)$
C_3H_8
C_6H_6
H_2S
$O_2(^{18}O)$
C_2H_4
C_2H_6
$CO_2(^{13}C)$
HCN
$O_2(^{17}O)$
C_2H_2
Ar
H_2O
CH_4
CH_3CCH
O_2
CO_2
SO_2
$CO_2(^{18}O)$
CH_3OH
$H_2O(^{18}O)$
H_2
$H_2(^2H)$
Resolution m/Δm
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9
10^{10}
%
ppm
ppb
Sensitivity (Abundance^{-1})



Project Manager's Update

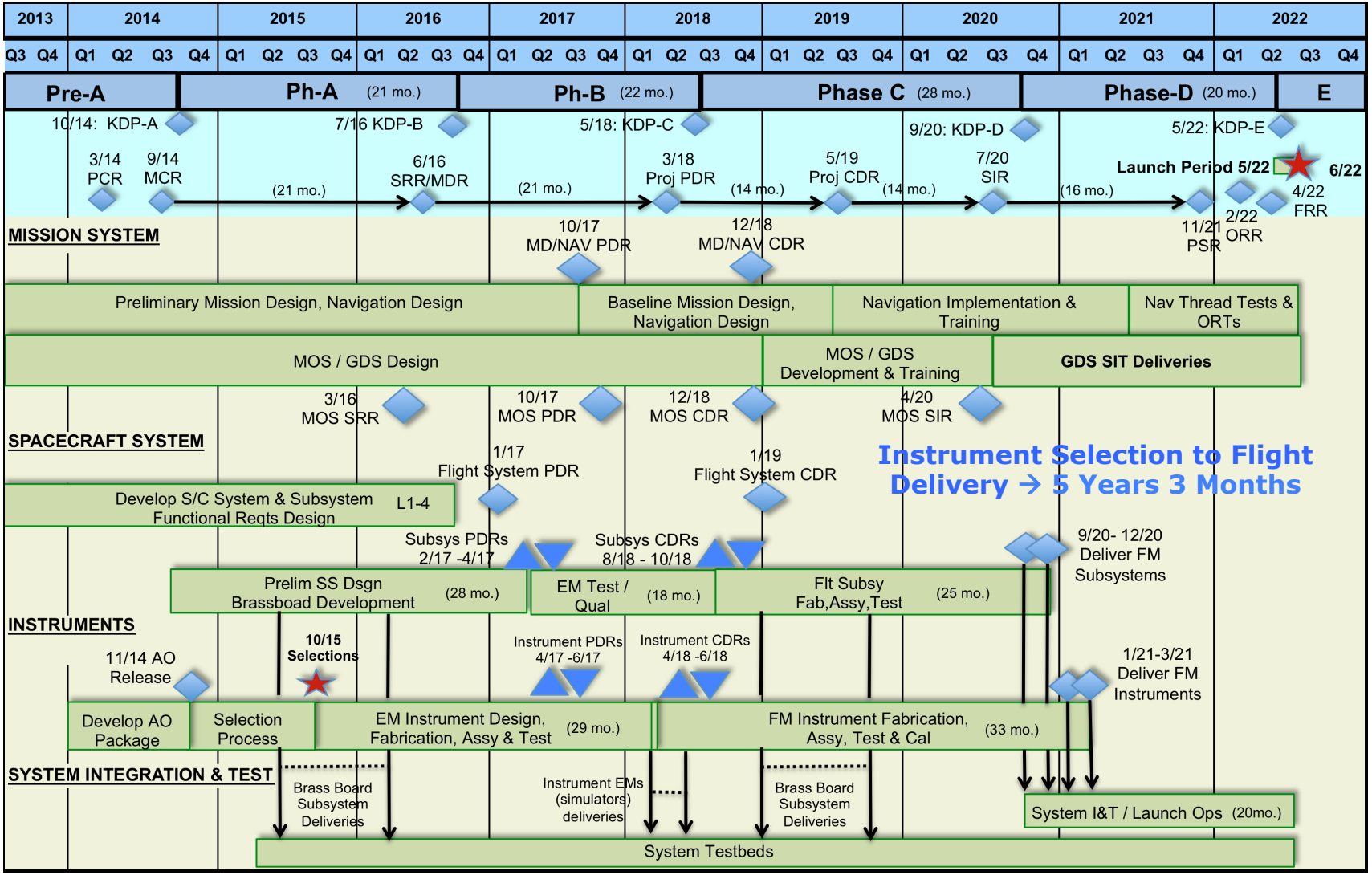
Barry Goldstein, JPL

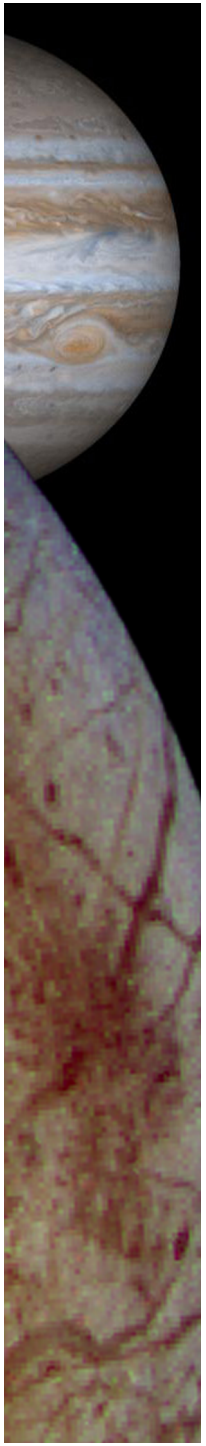


Recent Activities

- Started interacting with the NASA selected Instrument Concepts for Europa Exploration (ICEE) teams
- Conceived more cost effective way of performing the gravity science
  - Removed 2 articulated GS antennae and replaced with multiple body fixed fan beam
- Initiated science and technical risk reduction activities
- Continued to refine the technical design and **requirements** in preparation for a Preliminary Concept Review (PCR) **[March 11-12]** and Mission Concept Review (MCR) **[September 16-18]**
  - 18 **Notional** Level 1's (Will need HQ concurrence)
  - 213 Level 2's
  - 73 Level 3's
  - > 550 Level 4 and below
- Conducted an independent mission solar power feasibility review
- Continued assessments with the Space Launch System (SLS) Program Office on a potential launch vehicle

New Baseline Schedule (May 2022 Launch)





Candidate FY'14 Funding Activities (FY'13 funding → September MCR)

- **SRR / MDR preparations (Independent of KDP-A):**

1. Update Gate Products
2. Complete requirements down to level-3
3. Cost exercise/Phase B grass roots estimate
4. Iterations 9 & 10 (To be defined technical trades and activities)
5. NEPA activities (if still baseline MMRTG)
6. Engage SLS LV team to solidify LV requirements

- **Risk Reduction:**

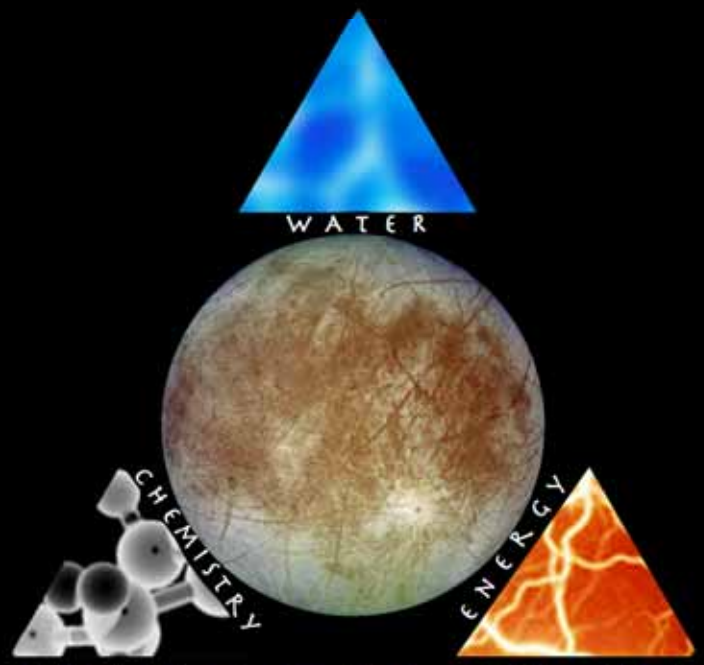
1. Procure and radiation screen FPGA's, Opto-isolators, Mass Memories
2. Continue pump life test; irradiated CFC-11 life test
3. All DHMR at risk hardware (e.g. battery) – develop sterilization plan, demos
4. Continue material testing for radiation & PP > will provide prioritized list
5. Solar: Radiation testing of new cells (UTJ)
6. Battery: Life testing of Panasonic cells; Cold temp electrolyte

- **Early development possibilities:**

1. Generation of complete coordinate-corrected Galileo image and mosaic database
2. Complete PIP and conflict of interest avoidance plan
3. Support NASA in proposal evaluation (assumes AO out early FY'15)
4. Telecom (Frontier Radio): Build brassboard with flight die (not packaging) / box level radiation test
5. C&DH: Begin redesign of MSL avionics into Clipper form-factor/Refactor FPGA's/Implement hibernation logic / Complete TTE testbed / Build brassboard / RFI&ROM with special focus on rad & PP/ Breadboard thermal pump electronics /conduct informal PDR
6. FSW: Complete Core FSW architecture / Develop FSW development plan / Adapt MSL device drivers / conduct informal PDR
7. Thermal: Procure CFC-11; / RFI&ROM with special focus on rad & PP
8. G&C: Evaluate baseline components vs. options (e.g, MIMU vs. ASTIX-120) / RFI&ROM with special focus on rad & PP/ SRU study contracts
9. Propulsion Module: Complete trade on engine configuration and commence with the requisite risk reduction activities/Active Press Control testbed; rad-hard press xdcr dev; rad-hard flow-meter dev; engine life test/ RFI&ROM with special focus on rad & PP/ME gimbal development/ME cover development
10. Power: Augment eMMRTG (if still MMRTG & RPS will not fund) / Begin design work on rad hard power electronics/Conduct informal PDR/Build brassboard version

THE EUROPA CLIPPER

• M I S S I O N •

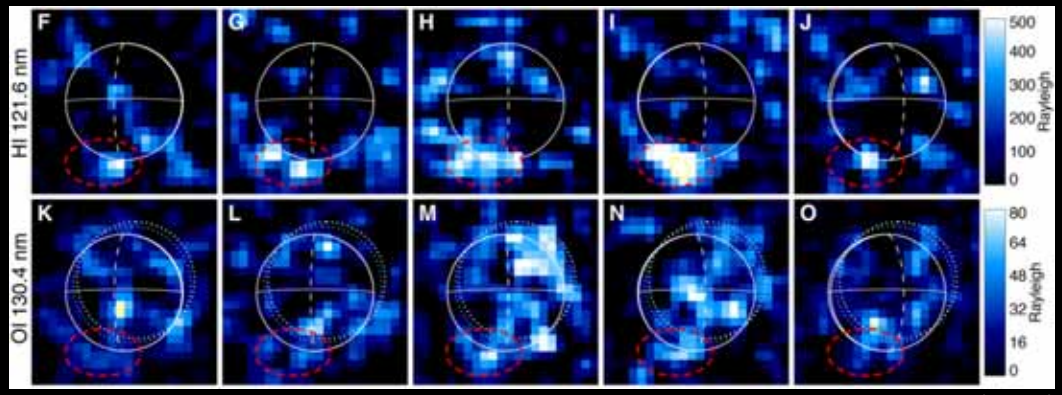


PLUME OBERSVATION STRATEGIES AND POTENTIAL TRAJECTORY MODIFICATIONS

B R E N T B U F F I N G T O N

MISSION DESIGN AND NAVIGATION

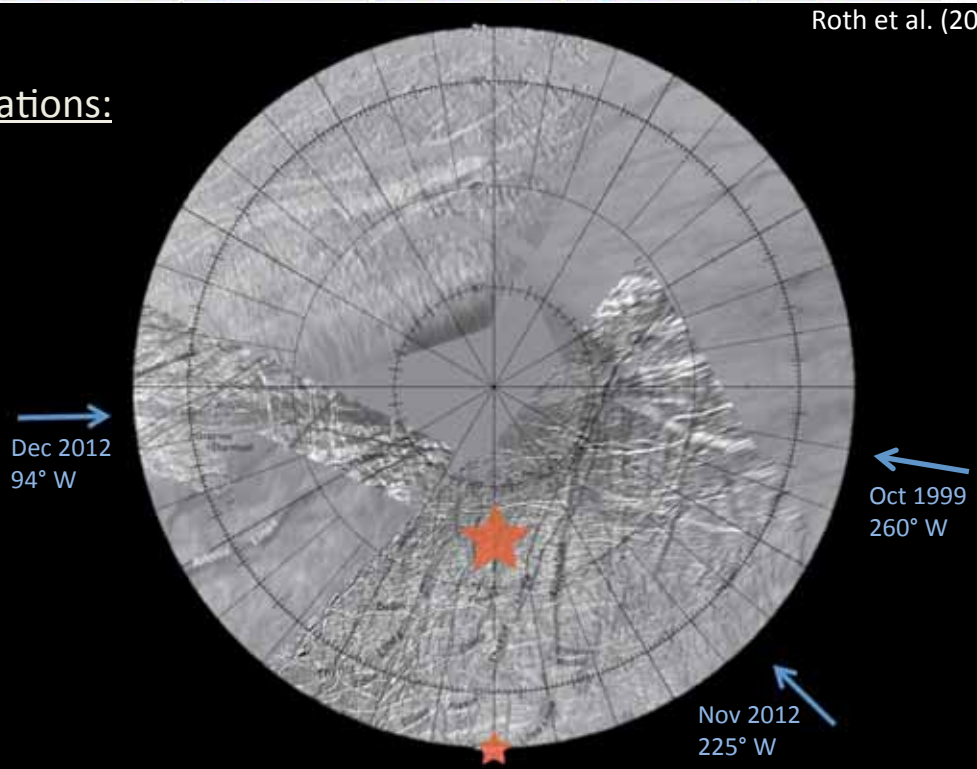
EUROPA PLUME(S)



Roth et al. (2013)

Plume Estimated Locations:

1) 55° S, 180° W
2) 75° S, 180° W

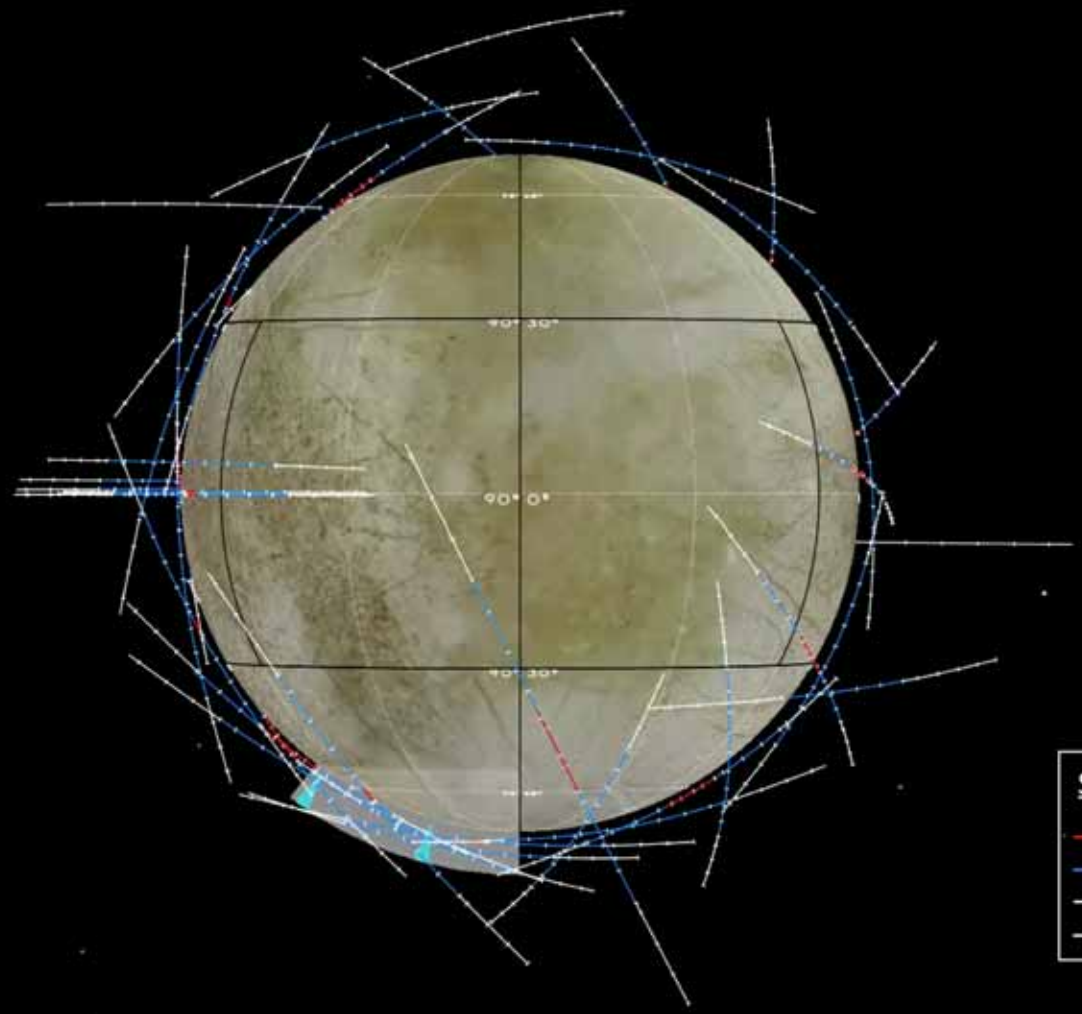


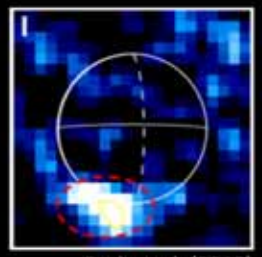
IN LIGHT OF PLUMES

- How does current Clipper mission do in investigating this phenomena?
- How can the Clipper mission be modified to capitalize on discovery?
- Is a multiple flyby mission still the best platform to explore Europa?

CURRENT CLIPPER TRAJECTORY

[IN SITU PLUME MEASUREMENTS]



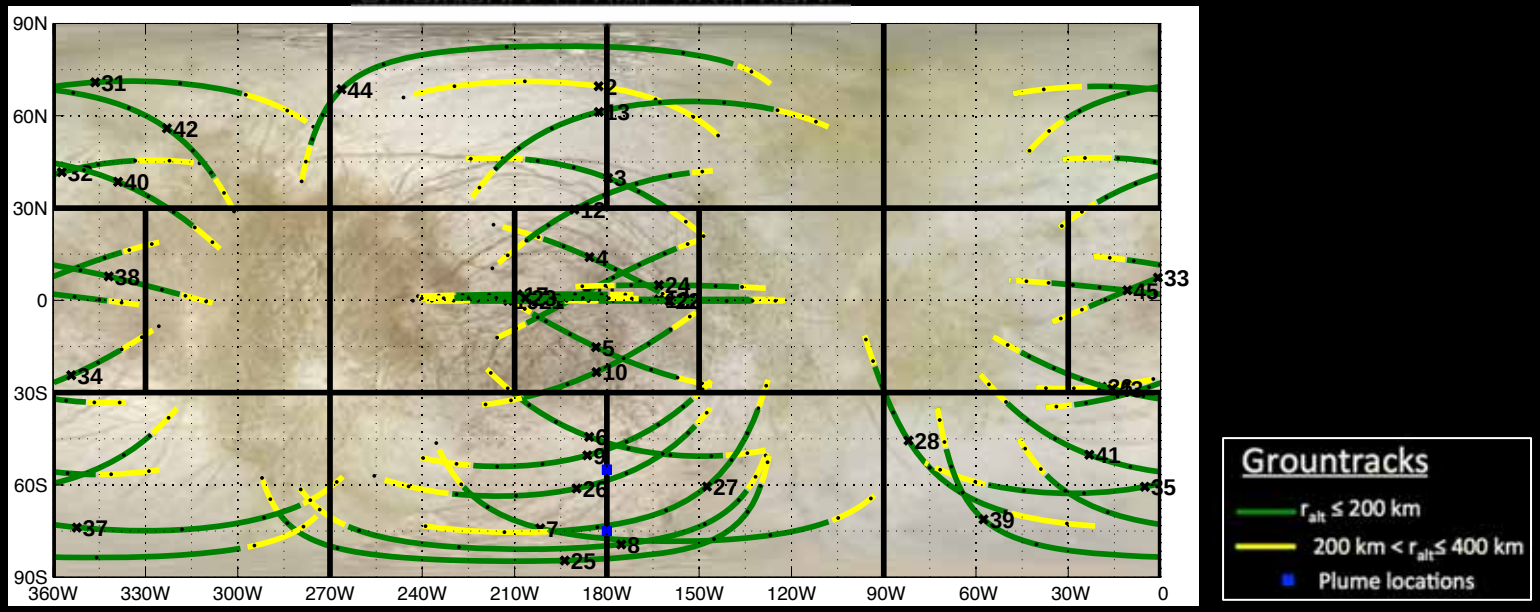


Roth et al. (2013)

CURRENT CLIPPER TRAJECTORY

[IN SITU PLUME MEASUREMENTS]

ATTAINABLE PLUME COVERAGE



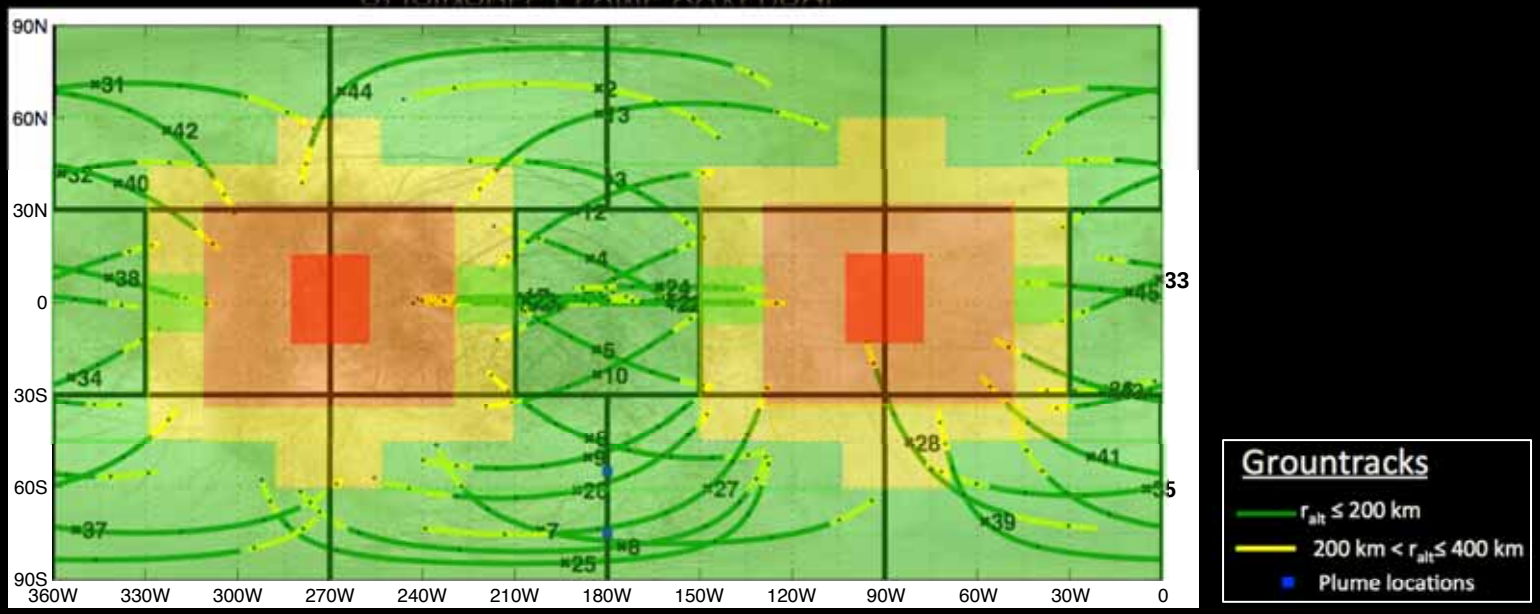
13F7 FLYBYS

Phase		Flyby		In/ Out	Date (ET)	Altitude (km)	B-Plane Ang (deg)	V_∞ (km/s)	Inc. (deg.)	Peri (R_J)	Apo (R_J)	SEP Angle (deg)	True Anom. (deg)	m	n	Period (days)
Jupiter Approach		Ganymede0	0G0	I	03-Apr-2028 11:58:34	500	0.1	7.97	5.4	12.96	265.1	156		N	R	200
Approach to Europa Science		Ganymede1	1G1	O	22-Oct-2028 17:14:57	100	-152.7	6.39	3.7	0.00	107.8	17		8	1	57.2
		Ganymede2	2G2	O	18-Dec-2028 23:07:28	100	-147.9	6.44	1.3	0.00	64.4	64		5	1	28.6
		Ganymede3	3G3	O	16-Jan-2029 13:49:12	1035.5	188	6.43	0.8	0.00	45.9	90		N	R	18.3
		Callisto1	4C1	I	31-Jan-2029 12:29:59	911.6	156.2	5.54	1.6	0.00	55.0	105		N	R	24.1
		Ganymede4	5G4	O	27-Feb-2029 18:42:49	523.6	163.5	5.24	0.2	0.00	37.0	133		N	R	14.6
		Callisto2	6C2	I	16-Mar-2029 06:22:27	2635.9	178.3	4.35	0.2	0.00	33.9	150		N	R	12.4
Europa Anti-Jupiter Hemisphere Coverage	COT-1	Europa1	7E1	O	25-Mar-2029 22:26:46	752.7	-36.2	4.00	1.4	0.00	38.0	161	120	4	1	14.2
		Europa2	8E2	O	09-Apr-2029 02:40:15	250	-71.1	3.93	3.8	0.00	37.9	176	127	4	1	14.2
		Europa3	9E3	O	23-Apr-2029 07:42:56	100	-44.3	3.96	5.7	0.00	37.9	168	138	4	1	14.2
		Europa4	10E4	O	07-May-2029 12:42:32	100	-15.9	3.97	6.3	0.00	37.8	152	149	4	1	14.2
		Europa5	11E5	I	21-May-2029 17:42:13	50	14.7	3.97	5.5	0.00	37.8	137	160	4	1	14.2
		Europa6	12E6	I	04-Jun-2029 22:42:16	25	46.7	3.96	3.3	0.00	37.9	123	172	4	1	14.2
	Non-Res (I/O)	Europa7	13E7	I	19-Jun-2029 03:44:29	100	78	3.93	0.5	0.00	38.1	109	183	4	1+	14.3
	COT-2	Europa8	14E8	O	03-Jul-2029 15:16:07	100	80.8	3.97	2.5	0.00	37.9	96	224	4	1	14.2
		Europa9	15E9	O	17-Jul-2029 20:14:27	25	53	3.99	4.7	0.00	37.9	84	235	4	1	14.2
		Europa10	16E10	O	01-Aug-2029 01:15:16	50	27.3	4.00	5.8	0.00	37.9	72	246	4	1	14.2
		Europa11	17E11	I	15-Aug-2029 06:11:34	25	-2.5	4.00	5.5	0.00	37.9	60	256	4	1	14.2
		Europa12	18E12	I	29-Aug-2029 11:07:50	50	-34.1	4.00	4.0	0.00	38.0	49	267	4	1	14.2
		Europa13	19E13	I	12-Sep-2029 16:00:57	25	-63	3.98	1.4	0.00	38.1	38	277	4	1	14.2
	Petal Rotation	Europa14	20E14	I	26-Sep-2029 21:15:22	565.2	-88.7	3.92	0.9	0.00	38.2	26	289	4	1+	14.3
		Europa15	21E15	O	11-Oct-2029 09:12:54	1872.2	21.6	3.96	0.6	0.00	41.9	15	329	9	2–	16.0
		Europa16	23E16	I	12-Nov-2029 01:39:22	2710.3	10.7	4.08	0.4	0.00	38.3	10	324	4	1+	14.3
		Europa17	24E17	O	26-Nov-2029 14:57:34	50	-1.9	4.02	0.4	0.00	45.5	21	11.0	5	1–	17.7
		Europa18	25E18	I	14-Dec-2029 04:40:32	50	-0.3	4.01	0.5	0.00	38.3	35	5.2	4	1+	14.3
		Europa19	26E19	O	28-Dec-2029 17:39:59	81.2	0.1	4.04	0.5	0.00	45.5	47	49.7	5	1–	17.7
		Europa20	27E20	I	15-Jan-2030 07:07:07	50	0.5	4.04	0.5	0.00	38.3	62	43.6	4	1+	14.3
		Europa21	28E21	O	29-Jan-2030 20:00:01	100	0.1	4.04	0.5	0.00	45.4	75	87.5	5	1–	17.7
		Europa22	29E22	I	16-Feb-2030 09:40:09	50	0.2	4.04	0.5	0.00	38.2	91	80.4	4	1+	14.3
		Europa23	30E23	O	02-Mar-2030 22:49:08	50	-0.8	4.08	0.4	0.00	45.4	105	125	5	1–	17.7
		Europa24	31E24	I	20-Mar-2030 12:05:36	100	-4.9	4.08	0.5	0.00	38.2	122	119	4	1+	14.3
Change Illuminated Hemisphere	Crank Up Pump Down	Europa25	32E25	O	04-Apr-2030 01:17:21	50	84.8	4.10	3.0	0.00	38.0	137	165	4	1	14.2
		Europa26	33E26	O	18-Apr-2030 06:13:37	50	63.1	4.12	5.4	0.00	37.9	153	176	4	1	14.2
		Europa27	34E27	O	02-May-2030 11:03:14	50	74.2	4.13	7.9	0.00	33.9	168	186	7	2	12.4
	Switch-Flip	Europa28	36E28	O	27-May-2030 07:36:51	25	109.5	4.14	10.4	0.00	26.9	165	203	N	R	9.5
		Callisto3	37C3	I	01-Jun-2030 20:43:23	466.5	-138	2.84	14.5	0.00	28.7	159		3	4	12.5
		Callisto4	41C4	I	21-Jul-2030 21:11:53	100	-98.8	2.84	19.0	0.00	28.7	109		1	1	16.7
		Callisto5	42C5	I	07-Aug-2030 12:47:17	1828.2	-64.1	2.84	20.1	26.11	29.6	94		pi-trans		16.7
		Callisto6	43C6	O	15-Aug-2030 18:43:56	100	-177.6	2.81	17.4	0.00	26.5	86		1	1	16.7
		Callisto7	44C7	I	01-Sep-2030 10:18:29	50	-40.7	2.83	13.6	0.00	30.8	72		2	3	11.1
		Callisto8	47C8	I	04-Oct-2030 17:52:50	25	-106.3	2.80	1.1	0.00	27.8	45		2	3	11.0
		Callisto9	50C9	I	07-Nov-2030 06:37:49	3673.1	-4.4	2.97	0.5	0.00	29.2	18		N	R	9.7
Europa Sub-Jupiter Hemisphere Coverage	Pump Up, Avoid Sol. Conj.	Europa29	53E29	I	09-Dec-2030 22:16:02	546.7	173.6	3.99	0.4	0.00	27.9	7	117	10	3+	11.8
		Europa30	56E30	O	14-Jan-2031 21:03:57	1009	-8.7	4.05	0.7	0.00	32.8	36	191	4	1–	14.1
	COT-3	Europa31	57E31	I	28-Jan-2031 18:06:21	100	-108.7	3.99	3.1	0.00	37.8	48	167	4	1	14.2
		Europa32	58E32	I	11-Feb-2031 23:08:16	100	-135.8	3.97	4.9	0.00	37.9	60	179	4	1	14.2
		Europa33	59E33	I	26-Feb-2031 04:12:04	50	-169.8	3.95	5.3	0.00	37.9	72	191	4	1	14.2
		Europa34	60E34	O	12-Mar-2031 09:13:49	50	152.7	3.96	3.9	0.00	37.9	84	203	4	1	14.2
		Europa35	61E35	O	26-Mar-2031 14:15:56	25	118.5	3.97	1.3	0.00	37.9	97	214	4	1	14.2
	Non-Res (O/I)	Europa36	62E36	O	09-Apr-2031 18:29:44	303.4	151.7	3.91	0.3	0.00	37.9	111	222	7	2–	12.4
	COT-4	Europa37	64E37	I	04-May-2031 06:22:09	50	105.1	3.89	3.1	0.00	33.9	135	204	7	2	12.4
		Europa38	66E38	I	29-May-2031 03:37:23	25	187.1	3.78	2.6	0.00	34.0	161	225	4	1	14.2
		Europa39	67E39	I	12-Jun-2031 07:37:03	50	96.4	3.81	5.5	0.00	37.9	177	231	7	2	12.4
		Europa40	69E40	I	07-Jul-2031 04:32:14	25	-139.5	3.79	3.5	0.00	33.9	157	252	4	1	14.2
		Europa41	70E41	I	21-Jul-2031 08:16:17	50	124.8	3.80	5.9	0.00	37.9	142	257	7	2	12.4
		Europa42	72E42	O	15-Aug-2031 05:17:42	50	-112.9	3.80	3.1	0.00	33.9	117	275	4	1	14.2
		Europa43	73E43	O	29-Aug-2031 08:56:27	25	-210.5	3.76	4.6	0.00	37.9	104	280	7	2	12.5
		Europa44	75E44	O	23-Sep-2031 05:37:41	50	-82.1	3.74	1.7	0.00	33.8	81	298	4	1	14.2
		Europa45	76E45	O	07-Oct-2031 08:47:53	25	-177.6	3.68	1.5	9.28	37.9	69	301	7	2	12.5

MODS TO CLIPPER TRAJECTORY

[IN SITU PLUME MEASUREMENTS]

ATTAINABLE PLUME COVERAGE



- For current Clipper tour design strategy ($v_\infty \approx 4$ km/s)
  - Green: Very easy to access
  - Yellow: Doable, but more complex set up
- Orange/red: Would requires higher relative velocities to increase inclination to fly close over leading/trailing hemispheres
  - Possible but would require more time to set up
- Ability to react to new discoveries a function of when discoveries are made and when next “close” (i.e., lat/lon) opportunity available to tweak

PLUME OBERVATION CAMPAIGN

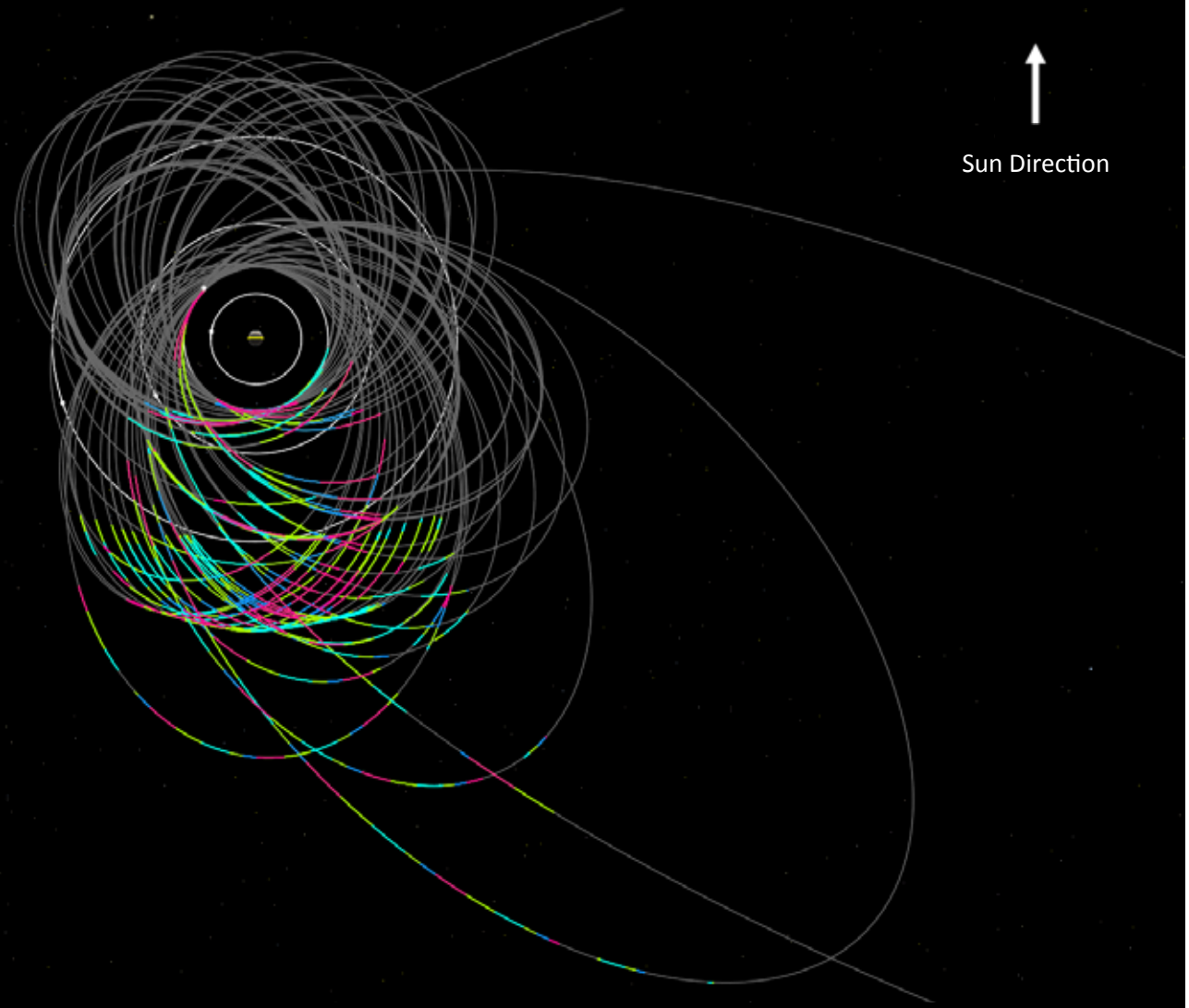
[HIGH PHASE OBSERVATIONS]

315° < Europa T.A. ≤ 45°

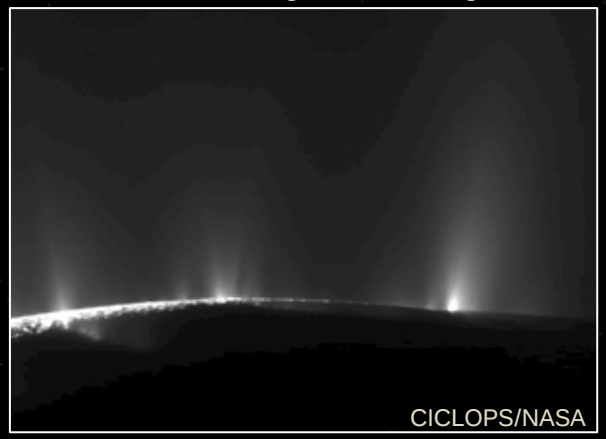
45° < Europa T.A. ≤ 135°

135° < Europa T.A. ≤ 225° *Includes apoapsis

225° < Europa T.A. ≤ 315°



Enceladus High Phase Image



SDT Next steps

Europa SDT Meeting

Feb. 4, 2014

JPL

Action items

- Consider whether SDT can be involved in Requirements review
- Consider whether we can circulate the instrument calibration plan
- SDT to provide input on candidate risk-reduction studies
- Schedule SDT telecon to present solar power trade
- Keep SDT informed of key mission trades
- Identify appropriate scientist(s) to perform plume modeling to understand potential for NMS detection of relevant species (including key ions and organics)
- Request Project to investigate implications of accommodating ROSINA-RTOF or JUICE NMS (mass, power, cost) given current margins
- Consider how science traceability matrix measurements might be augmented to accommodate potential plumes (Subgroups) – 4 weeks
- Is there any augmentation that would be required to the instruments or the mission design in order to achieve these measurements?
- Host a Europa plume "community forum" as input to support the mission concept, potentially in conjunction with SDT meeting

Subgroups

- **Ocean & Ice**
  - **Bills,** Bagenal, Kurth, Blankenship, Connerney, Smith, Pappalardo
- **Composition**
  - **Blaney**, McGrath, Hoehler, Hand, Shock, Brinckerhoff, Vance, Lorenz
- **Geology**
  - **Moore**, Senske, Mellon, Patterson

Science Traceability Matrix

Goal	Objective		Investigation	
Explore Europa to investigate its habitability	Ice Shell and Ocean	Characterize the ice shell and any subsurface water, including their heterogeneity, ocean properties, and the nature of surface-ice-ocean exchange.	IO.1	Characterize the distribution of any shallow subsurface water and the structure of the icy shell.
			IO.2	Determine Europa's magnetic induction response to estimate ocean salinity and thickness.
			IO.3	Search for an ice-ocean interface.
			IO.4	Correlate surface features and subsurface structure to investigate processes governing material exchange among the **ocean, ice shell, surface, and atmosphere**.
			IO.5	Determine the amplitude and phase of gravitational tides.
			IO.6	Characterize regional and global heat flow variations.
	Composition	Understand the habitability of Europa's ocean through composition and chemistry.	C.1	Characterize the composition and chemistry of the Europa ocean as expressed on the surface and in the atmosphere **including potential plumes**.
			C.2	Determine the role of Jupiter's radiation environment in processing materials on Europa.
			C.3	Characterize the chemical and compositional pathways in Europa's ocean.
	Geology	Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities.	G.1	Determine sites of most recent geological activity, **including potential plumes,** and characterize localities of high science interest.
			G.2	Determine the formation and three-dimensional characteristics of magmatic, tectonic, and impact landforms.

Reconnaissance Traceability Matrix

Goal	Objective		Investigation	
Characterize Safe and Scientifically Compelling Sites for a Future Lander Mission to Europa	Landing Safety	Assess the distribution of surface hazards, the load-bearing capacity of the surface, the structure of the subsurface, and the regolith thickness.	SL.1	Determine the distribution of blocks and other roughness elements within a potential landing site at scales that represent a hazard to landing.
			SL.2	Determine the distribution of slopes within a potential landing site over baselines relevant to a lander.
			SL.3	Characterize the regolith cohesiveness and slope stability within a potential landing site.
			SL.4	Determine the regolith thickness and whether subsurface layering is present within a potential landing site.
	Scientific Value	Assess the composition of surface materials, the geologic context of the surface, the potential for geologic activity, the proximity of near surface water, and the potential for active upwelling of ocean material.	SV.1	Characterize the composition and chemistry of potential landing sites with an emphasis on understanding the spatial distribution and degradation state of endogenically derived compounds.
			SV.2	Characterize the potential for recent exposure of subsurface ice or ocean material vs. degradation of the surface by weathering and erosion processes and provide geologic context for potential landing sites.
			SV.3	Characterize the potential for shallow crustal liquid water beneath or near potential landing sites.
			SV.4	Characterize anomalous temperatures (that are significantly out of equilibrium with expected nominal diurnal cycles) indicative of current or recent upwelling **or outgassing,**[of ocean material] at or near potential landing sites.

Feb 4, 2014 – Europa SDT meeting

<u>Notes</u>

Goals and agenda

- introductions included informing of ICEE involvement
- determine impact of plume discovery on trace matrix for science and recon, payload, trajectory
- science presentations will be given

Update by Curt Niebur

- MCR approved for project – Fall
    - Recognition by upper management that this is a mission to take seriously
- Congress' budget shows support for Europa and planetary science in general
    - $80M FY14
        - important to convey to stakeholders that mission is spending $ wisely
            - request SDT to continue to promote this to community
            - inform Louise, Bob, Curt of any criticism so we can present facts to them of wise spending

Bob Pappalardo – Science update

- recent presentations to SDT are posted on public website
- ICEE conversations are managed by Pappalardo and Vance
- Should SDT be involved with review of requirements documents
    - There are reviews planned
- Also might want to circulate calibration plan by SDT members
- Risk reduction tasks
    - Funding several unknowns – to reduce risk
        - Langmuir Probe
            - Can probe enable plasma correction for magnetometry?
        - laser altimeter – can we get h2?
        - plume detection – when could we do searches, etc.
    - results will be put out publicly in papers & presentations
    - Are there other ideas? Let the project know
    - Could NASA fund? Hard to make it an open call since Congress is specifying its purpose – Curt: Kept separate from ICEE projects
    - SDT is concerned about ICEE and risk reduction tasks come across as inside "hand-outs"; also concerned that studies are going to cause selection of instruments prematurely – i.e. studies might not be the right ones to do
        - Meant to validate model payload; better to have studies on other instrument capabilities that will be public – Barry
        - Fran – for her study makes point that her study is to determine measurements needed – not necessarily just for a Langmuir probe
        - SDT wants more involvement in which studies are approved

            - Will help with perception that selections are inside jobs
            - Mars project had some way of doing an open call for studies – project should look into this to see it was done
            - Also, if had two teams on each topic, it would appear more open
                - Though its been hard to get one team to do studies, but project will consider this
- Science communications –blog, graphics, video, science series
- Trajectory analysis
    - Tall tent poles show us areas of concerns

PM update – Barry

- Iteration 7 review just completed
    - Highlights:
        - conceived more cost effective ways to accomplish gravity science – fan beam antennae replaced articulated ones
            - explained to SDT member that articulated antennae were not part of Clipper initial design – i.e. not in cost cap
            - David Smith pointed out that laser can give good info on local thickness – support gravity and radar – uncertainties are really what will drive instruments needed
        - initiated science and technical risk reduction activities
            - radiation, planetary protection
        - refined technical design and requirements in prep for PCR in mid march (11-12) and MCR in mid sept.(16-18)
            - Have SDT members review science requirements documents
        - conducted independent review for solar power feasibility
            - Fran requested presentation on this study
                - Interested in science implications: trade looked at pointing, field of view, jitter/stability, electrical noise, etc. implications
            - Cost comparison? – Barry: significantly more expensive to fly MMRTGs
            - SDT - Why supporting MMRTG supply if we aren't going to use them for outer planet missions?
                - Curt: still in question for rate of development and fuel
                - Plenty of other missions that will want to use RTGs
                    - Past Jupiter, missions will really need them
                - Question remains as to final cost
                - Bob – telecom will be scheduled to go over solar study results
        - continued assessments of SLS launch vehicle

            - remain committed that mission will be compatible with both launch vehicles
- Baseline schedule
    - Driving factor – what will it take to get a payload suite ready
        - When will instrument selection occur? Need 10/15 or w/in a few months to keep on schedule
        - Launch dates – slipped to next opportunity 5/22 Atlas launch
            - SLS opportunity is only 3 wks after.
            - Slip to 5/22 makes trajectory with Atlas 7.2 yrs
                - Overall increase of time to Europa arrival of 1.5 yrs
            - Team is always designing to 4 launch opportunities
                - Shorter trajectory for a later Atlas launch (/23) will actually still get us there at same time as earlier 5/22 launch date

Science presentations

- Clay minerals – Shirley
    - Materials emplaced on the surface – chlorite group
    - Comet or asteroid impact?
        - Could then have Phyllosilicates, organics
        - Oblique impact can deposit material far from crater (100 km)
- Plume observations - Retherford
    - Emission surpluses consistent with two water vapor plumes ~ 200km high & 250 km w column densities $\sim 10^{20}$ m^{-2} n_0 $\sim 10^{15}$ m^{-2}
        - Roth et al (2014), Science
    - Auroal variability is definitely something we should study more
    - Can plume activity be accurately enough predicted to plan fly-bys?
    - Ralph- what are JUICE's capabilities to detect these:
        - Project is giving credence to this and will do some recon on the topic before the Europa flybys
        - Ralph-Will NASA say that since JUICE is doing this, do we need Clipper to?
            - Will wait until Clipper is real mission before opening possibility to collaborate with ESA
- Subduction – Prockter
    - Could have implications for mission planning
    - Areas of contraction are questionable, few and far-between – so where is it occurring?
    - Subduction zones?
        - Tabular bands observed at N. high latitudes ~ 30 km wide
        - Missing surface area
            - Up to 90km of missing material in some places
        - Boundaries have very different morphology from usual
        - Topographic conundrum
            - No evidence of elevated terrain

            - May have cryovolcanic features with surface flows – all on overriding plate
            - Color is different from surrounding terrain – white, very bright
        - Potential astrobiological significance
        - Could be only other place in solar system that has plate tectonics

Trace matrices –Senske, Prockter

- To SDT – Send any Sci trace matrix comments to Dave Senske
    - Dave has sent around electronically
- Mapping resolution discussion
    - Fran – can we determine what places are most interesting now?
        - Need more coverage first really – we don't know enough now, except for a few places we think will be interesting
- To SDT - In particular, related to plume discovery, any proposed changes?
    - C1 –composition – add "potential" plumes here
        - SDT says yes, add wording for plumes to C.1
    - Suggested to also put under "recent activity and geology" – suggested to put it in G.1, not in overall G.
        - Add after "activity" "including potential plumes"
    - IO.4 – Don suggests could be explicit here to include atmosphere interaction wording (not put before surface, ice, and ocean)
        - Change to "ocean, ice shell, surface, and atmosphere"
    - Chose "potential" wording over "putative" or "candidate" as those are limiting
    - Question about what would Cassini have liked to have to better done to understand Enceladus' plumes?
        - a mass spec that went up to higher masses
    - Can clipper detect C and N in plume material?
        - Absolutely essential to determining habitability
        - Although a plume is a proxy to what's actually in the ocean
        - "It is hard to get what you need…"
    - Ralph - would a dust instrument be worth studying to see what it could give us?
        - UV instrument?
- Should we (SDT) be thinking about international instrument contributions? If we want to think about other instruments– Ralph
    - Curt – people can propose anything, but would have to fit within mass, cost, power budgets
        - Is more mass for the payload worth taking it from somewhere else? As a team, we collectively have to make those decisions
    - Louise – maybe we should consider some of these
- Move to get back to ranking observations, rather than instruments
    - Really trying to investigate habitability
        - What is the best proxy? Composition is key

        - Suggested you don't need an INMS, but a capable NMS
            - Range and sensitivity of NMS, adequate mass resolution
- High phase imaging could help with plume observations
- Suggest we need a mass spec similar to Rosetta's
    - Project requests suggestions on a lead for a study on this – a plume working group?
        - Will use Cassini and Icy Worlds workshop as initial conversation avenue.

LUNCH

Summarizing discussion before lunch:
Provide input from your area of expertise related to plume detection and what observations you think are needed
What additional capability might be needed?

Melissa McGrath presented a chart on NMS, INMS resolution and sensitivity at 100 km altitude for certain assumed atmosphere

- Shows suggested Rosetta RTOF spectrometer – request info from project how much this change would cost, require increases in power, mass
- Hydrocarbons are outside of range of these spectrometers
    - Initial calculations do not consider flying through a plume, to detect elements would imply lower required sensitivity, although type of organic molecules would not be resolved
- with possibility of plumes, would we be remiss not to fly an Mass Spec with more capability than that on Cassini, which we know could be better for analyzing Enceladus' plumes
- so which to improve? Resolution or sensitivity?
- Would like to see more items on the example plot: salts, amino acids
- Mass vs. altitude plot might be more informative (provided by Tim Cassidy)
- If using Enceladus as first-order analogy – what would we fly?
- Shock: want to measure salts

Revisited prioritization of instruments

What's the "Sweet-spot" measurement range we'd want with a mass spec?

Hand: Want to increase range of molecules – larger mass parent molecules
ROSINA (Rosetta) might be a good model instrument

- Not much greater in mass

Everyone think if this minimum for NMS is good enough

Buffington – trajectory – plume observing scenarios

- 7 flybys that go through putative plume areas (E6-9 and E25-27)
- pretty hard to fly over leading and trailing hemispheres, would need high V_{inf}
- but otherwise can modify fly-by locations of closest approach fairly easily

Maybe implications for flying through plumes such as modification of instrument shielding etc. that need to be considered

Recon trace matrix
SV.4 added “or outgassing” “-of ocean material”

Next Steps

- Breaking into sub groups to take a look at Ocean & Ice, Composition, Geology over the next 4 weeks and see what needs to be done to consider plumes
- Update science trace matrix according to your results; list in word document which cells you want to change and what change needs to be made.
- What future studies do we want to see to help with confirming or characterizing plumes
    - Archival project, looking through old data from other missions to see if they saw anything
    - Brainstorming plume workshop – attach to SDT meeting
- Telecon in about a month
- Keep option open to have another SDT mtg. – might attach to workshop
- Shock: understanding what is happening to the salts as they come out of the plume is important
- What does the magnetosphere do to them?