National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology

Soil Moisture Active Passive Mission

SMAP

4th Cal/Val Workshop

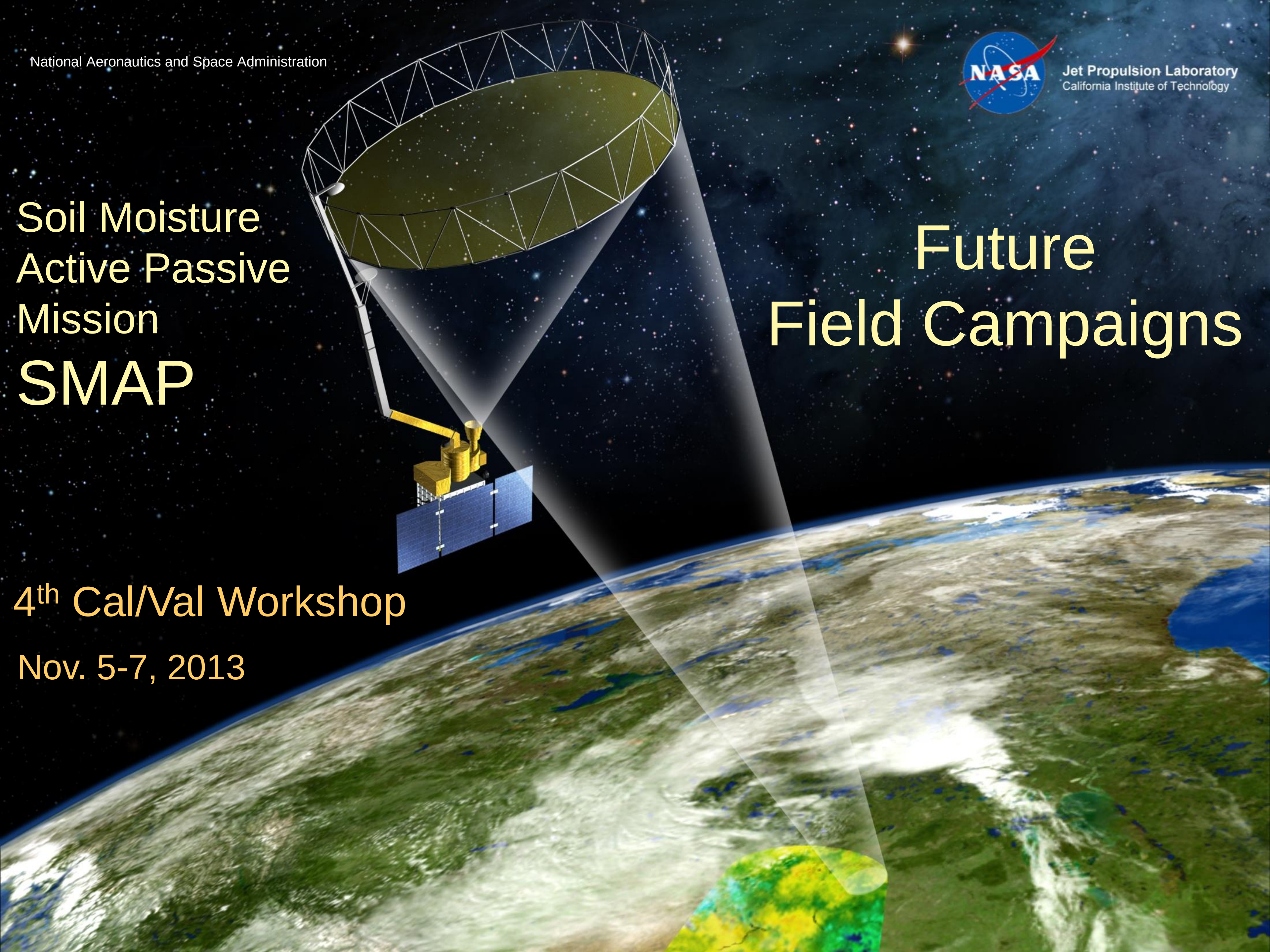
Nov. 5-7, 2013

Workshop Overview

- Project Status
- Cal/Val Overview
- Phase 1 Rehearsal
- Cal/Val Partners
- L1 Cal/Val Plan
  - Overview
  - Topics
  - Inter-calibration/satellite programs
- L2-L4 Topics
  - In situ sensors
  - Sparse networks
  - Field experiments
  - Triple Co-location
- Phase 2 Rehearsal

Cal/Val Workshop Agenda-Day 2

Wednesday (November 6)		
	Level 1 Cal/Val Plan and Activities	*Spencer (Lead)*
0815	Project Level 1 Cal/Val Plan Overview	Spencer
0845	Radiometer Cal/Val Activities	Kim
0915	Radar Cal/Val Activities	West
0945	*Break*	
	L1 Cal/Val Topics and Discussion	Spencer
1000	Radiometer Cal/Val Techniques/Targets	Misra
1020	Dome-C Aircraft Experiment	Skou
	Inter-Calibration and Satellite Updates	Spencer
1040	SMOS/Aquarius Working Group Status	LeVine
1110	SMOS/Aquarius Inter-Calibration Results	Bindlish
1130	Aquarius Radar Inter-calibration	Fore
1150	*Discussion*	
1200	*Lunch*	
	L2-L4 Topics: In Situ Sensors and Networks	*Cosh (Lead)*
1300	Marena OK In Situ Sensor Testbed (MOISST)	Cosh
1330	CRN	Bell
1345	OK Mesonet	Basara
1400	NEON	Ayres
1415	Canadian FT Sites	Belair
1430	*Posters/Break*	
	L2-L4 Topics: Field Experiments	*Jackson (Lead)*
1530	SMAPVEX12 Archive	Colliander
1545	ComRAD	O'Neill
1600	Future Field Campaigns	Jackson
1630	Discussion	
1700	*End*	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L2-L4 Validation Methodologies

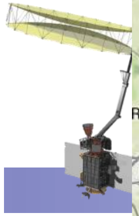
Methodology	Role	Constraints	Resolution
Core Validation Sites	Accurate estimates of products at matching scales for a limited set of conditions	• In situ sensor calibration • Limited number of sites	• In Situ Testbed • Cal/Val Partners
Sparse Networks	One point in the grid cell for a wide range of conditions	• In situ sensor calibration • Up-scaling • Limited number of sites	• In Situ Testbed • Scaling methods • Cal/Val Partners
Satellite Products	Estimates over a very wide range of conditions at matching scales	• Validation • Comparability • Continuity	• Validation studies • Distribution matching
Model Products	Estimates over a very wide range of conditions at matching scales	• Validation • Comparability	• Validation studies • Distribution matching
Field Campaigns	Detailed estimates for a very limited set of conditions	• Resources • Schedule conflicts	• Airborne simulators • Partnerships

Future Field Campaigns

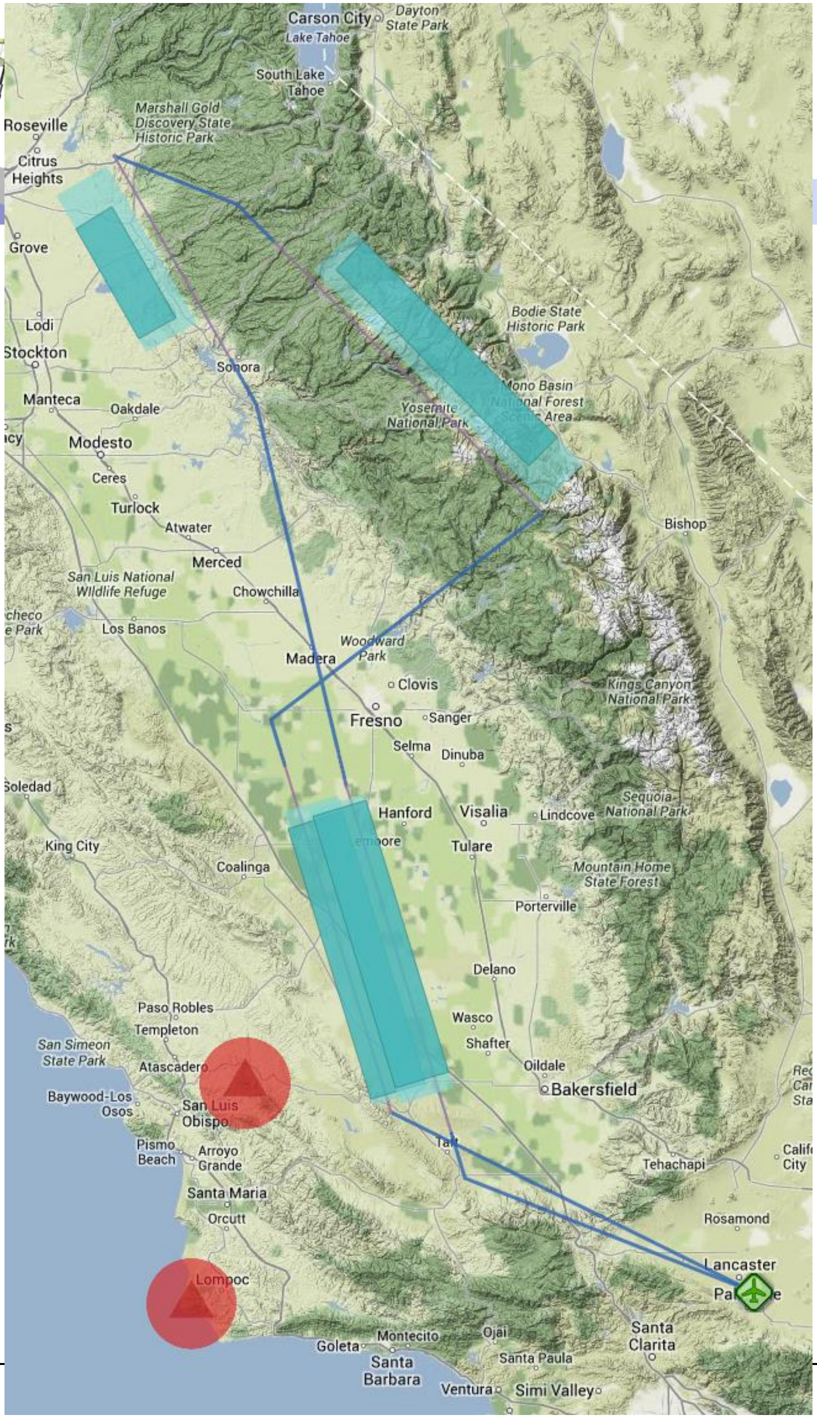
- UAVSAR 2014
- Post-Launch (SMAPVEX16)

SMAP FY2014 UAVSAR Flights

- Targets
  - *California*
    - Sites
      - Snow (Simon)
      - Tonzi Ranch (Sab)
      - SJV (Sab)
    - Temporal: 8 times between November 25, 2013 and August 8, 2014. (N/A April 2014)
  - *South America*
    - Amazon
      - April 2014
      - L1 radar calibration sites
      - Priority to Site03 because it falls within the PALSAR2 cal box
      - Interested in any other flights that are planned by other groups into the Amazon domain.
        - » Reviewing sites proposed by other teams.



SMAP-CA Sites



	Takeoff Airport (KPMD)	0 min	0 km
	Transit to Line SnJoaq_34301	16 min total 31 min	139 km total 139 km
+	1. Line **SnJoaq_34301**	11 min 41 min	145 km 284 km
	Transit to Line tjac07_330aa	18 min 60 min	174 km 458 km
+	2. Line **tjac07_330aa**	7 min 1 hr 6 min	91 km 550 km
	Transit to Line tjac05_135aa	10 min 1 hr 17 min	70 km 620 km
+	3. Line **tjac05_135aa**	11 min 1 hr 28 min	149 km 769 km
	Transit to Line SnJoaq_16301	16 min 1 hr 44 min	143 km 911 km
+	4. Line **SnJoaq_16301**	11 min 1 hr 55 min	145 km 1,056 km
	Transit to Landing	27 min 2 hrs 22 min	165 km 1,221 km
	Landing Airport (KPMD)	2 hrs 22 min	1,221 km

If you need to estimate costs for using UAVSAR:

NASA approved investigation (i.e. ROSES):

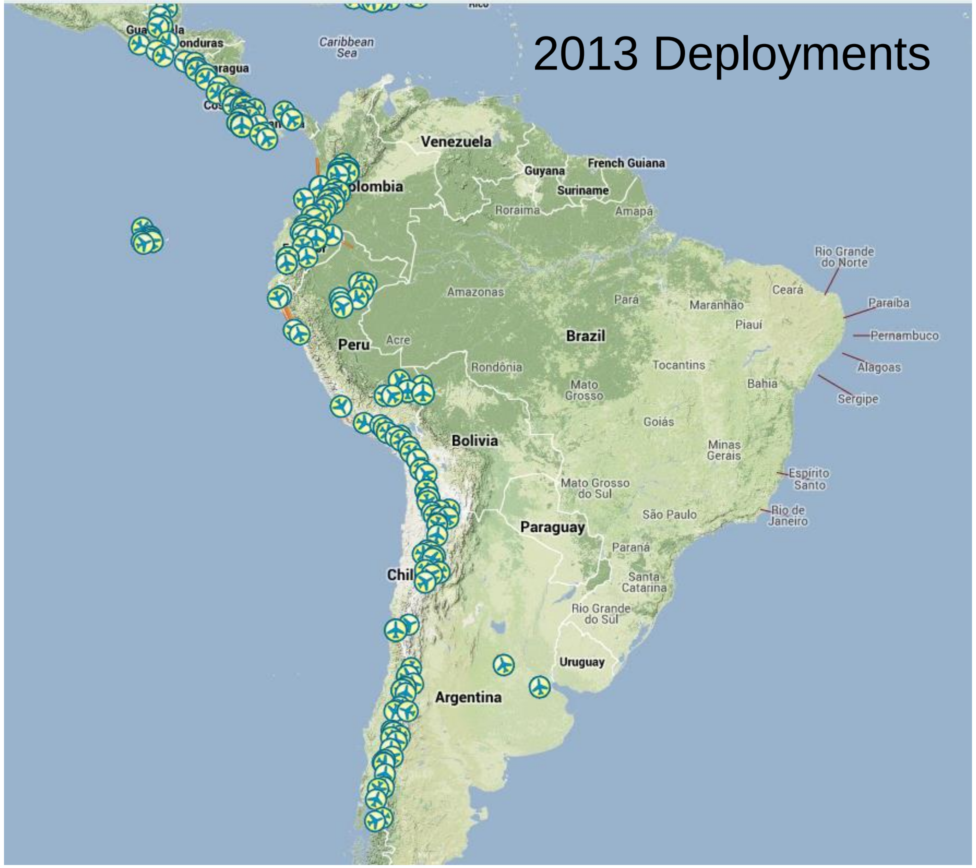
Estimated cost for this flight plan is $7K

- Plus any mission peculiar costs.

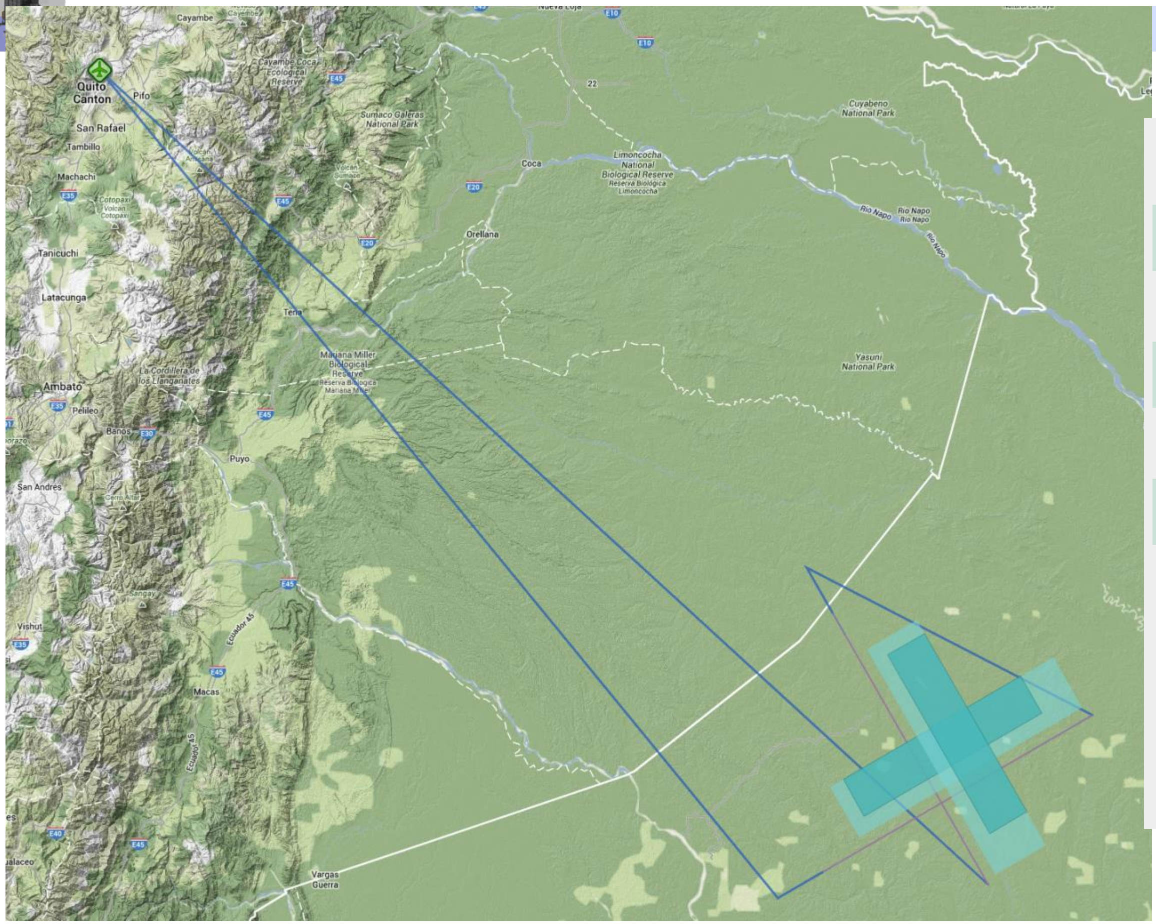
Based on $3000 per flight hour.

South America

- There will be a deployment in April 2014
- Follow-on to 2013
- Dense forests are used for radar calibration
- Linkage to PALSAR-2



SMAP- Peru Site03



Takeoff Airport (SEQU)	0 min	0 km
Transit to Line SMAP03_060aa	36 min total 51 min	417 km total 417 km
1. Line **SMAP03_060aa**	9 min 1 hr 1 min	121 km 538 km
Transit to Line SMAP03_150aa	13 min 1 hr 14 min	108 km 647 km
2. Line **SMAP03_150aa**	9 min 1 hr 23 min	121 km 768 km
Transit to Landing	50 min 2 hrs 13 min	466 km 1,234 km
Landing Airport (SEQU)	2 hrs 13 min	1,234 km

If you need to estimate costs for using UAVSAR:

NASA approved investigation (i.e. ROSES):

Estimated cost for this flight plan is $7K

- Plus any mission peculiar costs.

Based on $3000 per flight hour.

SMAP- Peru Site01

Takeoff Airport (SPIM)	0 min	0 km
Transit to Line SMAP01_060aa	49 min total 1 hr 4 min	578 km total 578 km
1. Line **SMAP01_060aa**	9 min 1 hr 13 min	121 km 699 km
Transit to Line SMAP01_150aa	13 min 1 hr 26 min	108 km 808 km
2. Line **SMAP01_150aa**	9 min 1 hr 35 min	121 km 929 km
Transit to Landing	1 hr 3 min 2 hrs 38 min	641 km 1,570 km
Landing Airport (SPIM)	2 hrs 38 min	1,570 km

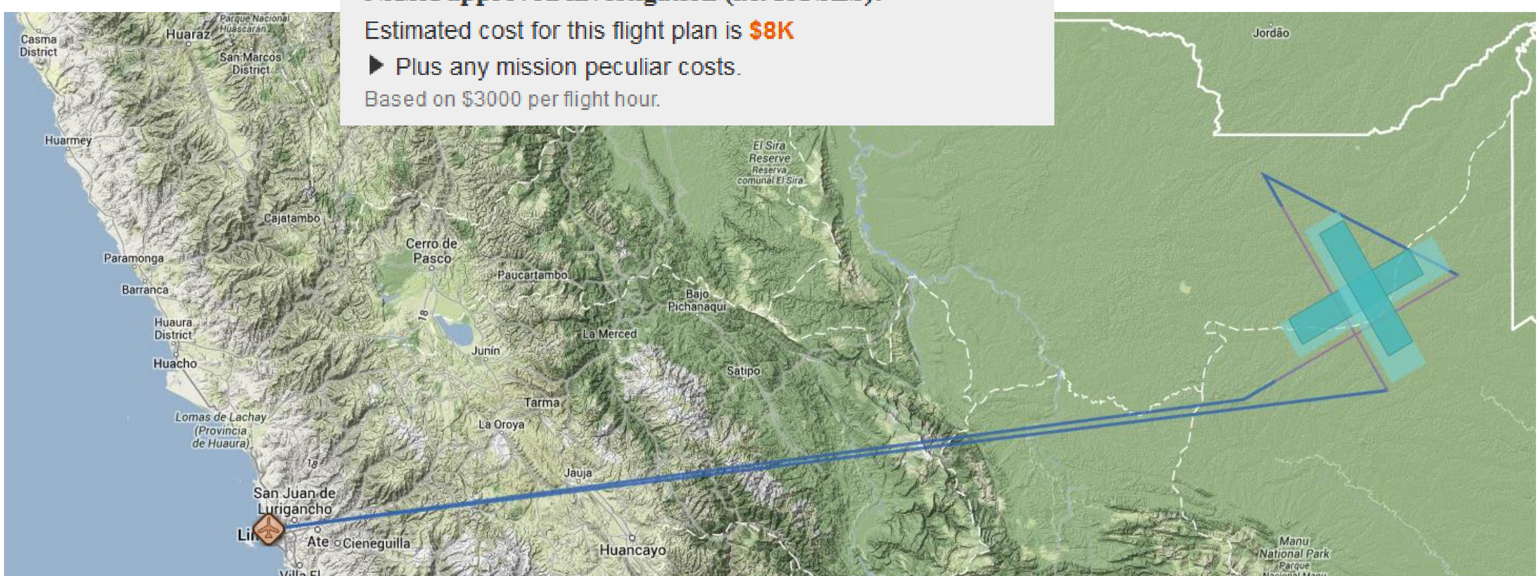
If you need to estimate costs for using UAVSAR:

NASA approved investigation (i.e. ROSES):

Estimated cost for this flight plan is **$8K**

▶ Plus any mission peculiar costs.

Based on $3000 per flight hour.



SMAP FY2014 UAVSAR Flights

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Post-Launch Aircraft Experiments Science Objectives

- *Validate the entire L2_SM_AP algorithm process; scaling and radiative transfer*

  Can only be accomplished with an aircraft simulator
- Understand the effects and contribution of heterogeneity on coarser resolution retrievals
- Evaluate the impact of known RFI sources on retrieval
- *Investigate and resolve anomalous observations and products*

  Requires that we have an adequate data record (2016)
- Correlative analysis of L1 product calibration and heterogeneity effects

  Cal/Val continues through the mission life

*The following discussion focuses on the first item. Other objectives can be integrated as they develop.

Post-Launch Aircraft Experiments Background

- SMAP provides soil moisture (SM) at 3 spatial resolutions; L2_SM_P (36 km), L2_SM_AP (9 km), and L2_SM_A (3 km).
  - *Of these the “flagship” SMAP product is the L2_SM_AP at 9 km; this drove the mission design and will satisfy the L1 mission requirements.*
- The current/baseline active passive (AP) algorithm uses the P and A observations to generate a “brightness temperature (TB)” (disaggregated brightness temperature) at a 9 km resolution. SM is then retrieved using the L2_SM_P algorithm.
- The SMAP Cal/Val program will provide in situ, satellite, and model products that can be used to validate the products. However, none of these resources can validate the entire L2_SM_AP retrieval process (disaggregation and retrieval) on a L2_SM_P basis.
  - *Validating the disaggregation approach and the SM at 9 km will provide increased confidence in the product and/or insights that can be implemented to improve the algorithm.*

Post-Launch Aircraft Experiments
Aircraft Experiment Concept

- Flights over one or more L2_SM_P grid cells at a Cal/Val site
  - *Possibly for multiple sites with different conditions (i.e. Canada, Arizona, Oklahoma,…).*
  - *More sites are desirable but the number feasible will depend on the final aircraft instrument design and budget.*
- Key requirement is higher spatial resolution TB coverage of the entire site that can be used to generate TB values for the L2_SM_AP (9 km) as well as the L2_SM_A grid (3 km).
- The SMAP L2_SM_P algorithm would be used with this data to generate SM products at both 3 and 9 km
- Ground sampling to validate higher spatial resolution retrievals.
- The algorithms also require radar observations.
- A variety of soil moisture conditions is needed for a robust analysis. Therefore, several flights should be conducted over a two week period concurrent with SMAP overpasses.
- Further refinement of the science objectives and campaign justification will be developed in collaboration with the SMAP Algorithm, Cal/Val and Science Teams.

Post-Launch Aircraft Experiment Contributions to Validation

- L2_SM_AP product over an entire L2_SM_P grid cell
- L2_SM_P product
- L2_SM_A product over an entire L2_SM_P grid cell
- SMAP TB and the aircraft TB over the L2_SM _P grid cell (Correlative analysis)
- Disaggregated brightness temperature at 9 km produced as an intermediate step in the L2_SM_AP algorithm. This is a very important contribution that can only be achieved using aircraft.(Correlative analysis)
- SMAP σ^o and aircraft σ^o over the L2_SM _P grid cell (Correlative analysis)

Post-Launch Aircraft Experiment Requirements

- An aircraft-based passive instrument is an essential requirement since it is the only means by which the process of brightness temperature disaggregation can be assessed.
- The availability of an integrated radar is desirable because it would support additional validation of the radar products.
- The aircraft based radiometer must be capable of providing coverage of an entire SMAP L2_SM_P grid cell within ~3 hours in order to minimize diurnal temperature effects.
- Spatial resolution of 3 km or better is desirable if all objectives are to be satisfied.
- The instrument must be stable during flights and well calibrated.
- The incidence angle should be centered at 40 degrees and the beam width should be as small as possible considering all other constraints. The antenna pattern should be well known.
- Currently there are no instruments that can fully satisfy the requirements described above.

Post-Launch Aircraft Experiment Mission Design Options

Long Time Series	Snapshots	Mix (Baseline)
		

Long Time Series

- Manitoba
- Option A: Continuous
  - *June 15-August 1, 2016*
- Option B: Split
  - *May 15—June 1, and July 1-15, August 15-30, 2016*
- SMAPVEX12 provided and excellent rehearsal

Snapshots

- Core Validation Sites (9)
- Two flights over each site
- July 15-August 30, 2016

Mix (Baseline)

- Subset of Core Validation Sites (3)
- Six flights over each (~2 weeks)
- July 15-August 30, 2016

The decision on how many sites and where to conduct the experiment must take into account both costs and logistics. Three options were considered; a long time series at one site, short-term coverage at many sites, and moderate-term coverage at a few sites. Consensus favored the third option of about 3 sites with two weeks of flights.

Post-Launch Aircraft Experiment Schedule Considerations

- There are two options currently under consideration (North America) summer 2015 and 2016.
- Important logistical consideration: many key project personnel will be tied up during the first year after launch to focus on the analysis of the SMAP data set and will not be available to support a field campaign or analyze the data.
- Another reality: if a field campaign is conducted in summer 2015 it is unlikely to be fully processed and analyzed by the end of the Cal/Val Phase.
- Unlikely that an instrument will be ready.
- Potential aircraft conflicts.
- 2016 is recommended.

SMAPVEX16

- Duration: 45 days (10 days for each site and 3 days for transit between sites
- Flight hours: 150 (120 for science and 30 for test flights and transit.)
- Two Aircrafts: PALS on P-3 (or equivalent) and UAVSAR on G3
- Three sites: each site will cover 36 km x 36 km
  - *Winnipeg*
  - *Two more sites selected based on the SMAP data collected in 2015*

SMAPVEX16 Instrument/Aircraft Plan

- PALS will be converted to PALScan by Oct. 1, 2015
  - *This modification is necessary to satisfy experiment spatial and temporal requirements.*
- Aircraft support
  - *Each aircraft involves different installation and integration issues. These involve significant costs and time. Down select is critical to efficiency and meeting time constraints.*
  - *There are many disciplines that utilize these aircraft. The sooner we identify and request an aircraft (preferably one with no known conflicts), the more likely we are to get it.*

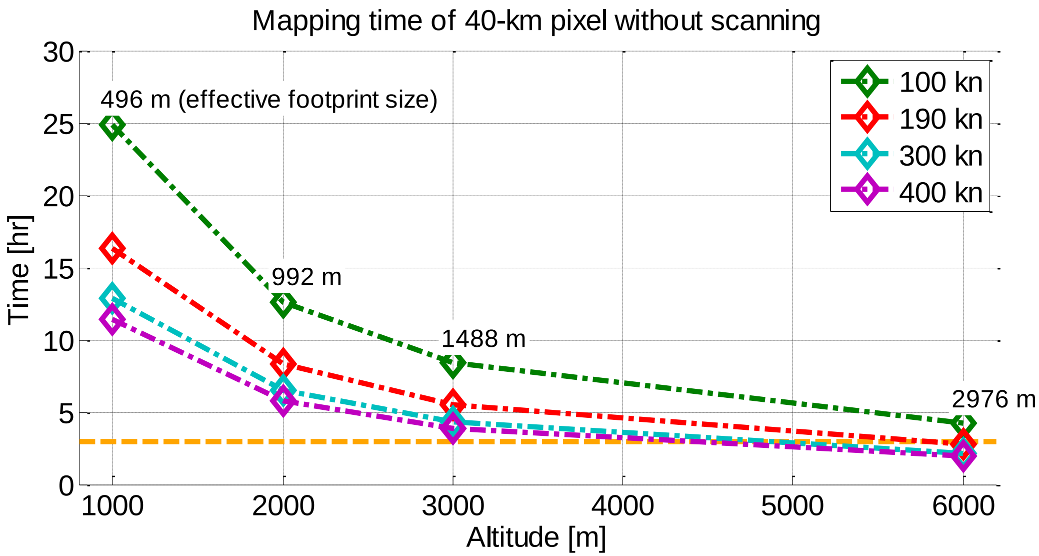
SMAPVEX16 Aircraft Options

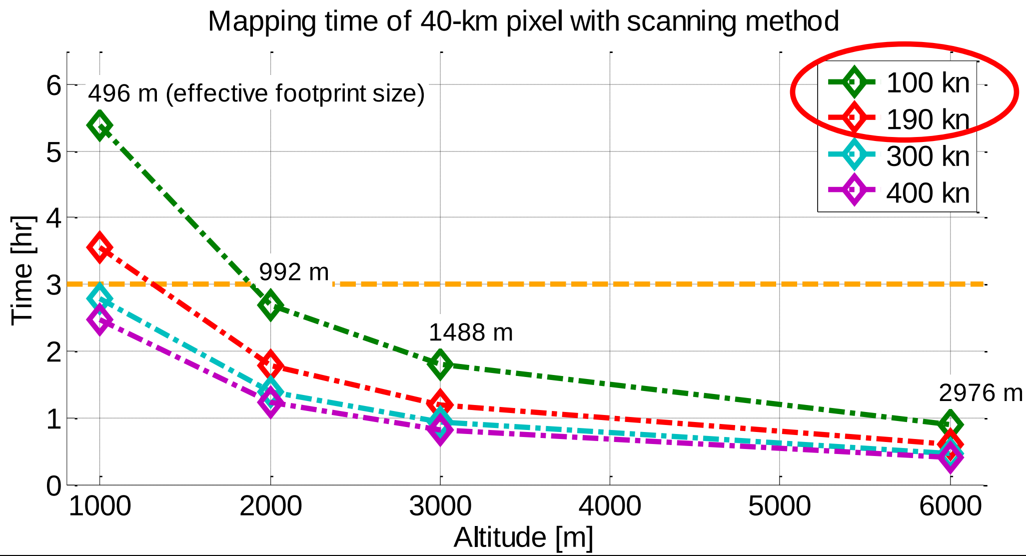
- Discussions with Canada suggested that there were integration issues that would likely prevent the use on their aircraft.
- S. Dinardo conducted an assessment of NASA aircraft options compatible with PALScan.
  - *P-3*
  - *C-130*
  - *C-23*
- Cost estimates ranged about 25% from highest to lowest (P-3>C-130>C-23)
- Airspeed (without instrumentation) also has the same order
- The P-3 speed will be limited by the exterior radome (TBD)
- The integration time of the instrument may limit the airspeed during data collection. Therefore, the only advantage of additional speed capability is during transits (not that large)

SMAPVEX16 Aircraft Recommendation

- Based upon the cost and lack of conflicts; the C-23
- If additional payloads (other instruments) or experiment requirements (Higher altitude or long transit distances) are identified, the C-130 may be a better option.

Non-scanning vs. Scanning

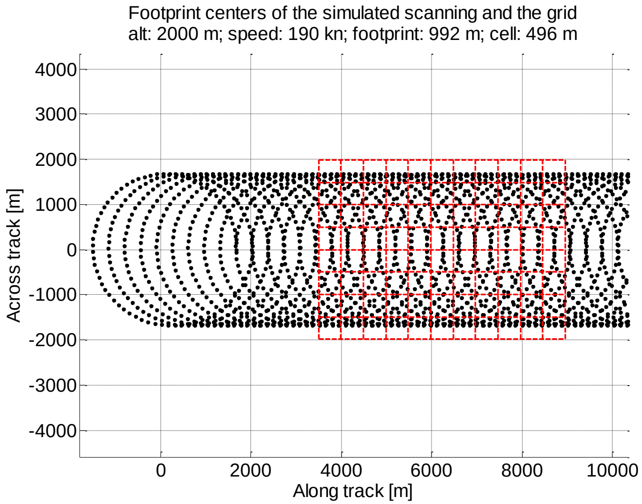


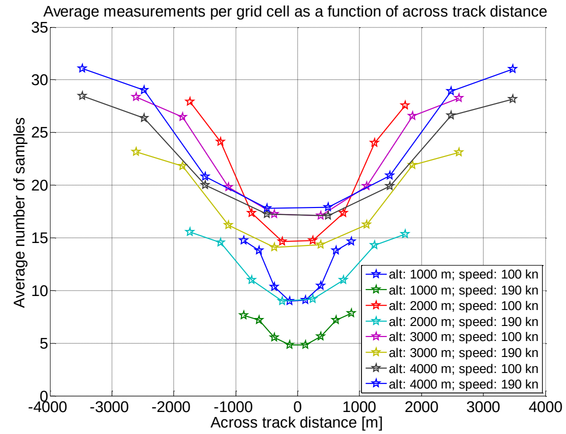


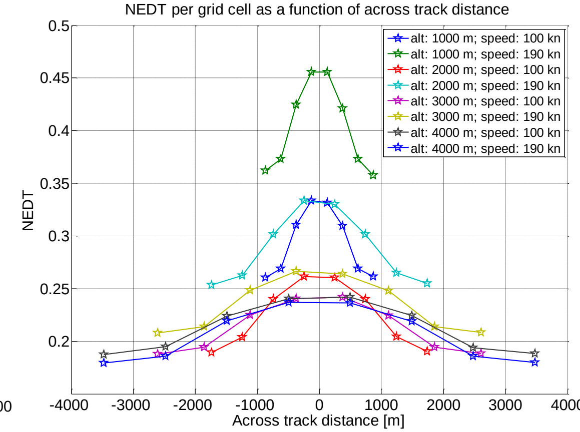
Total mapping time of a 40-km pixel as function of the flight altitude (which determines the footprint size shown in the plot) at different flight speeds: (a) without scanning and (b) with scanning.

Orange line highlights the 3-hour threshold for adequately efficient mapping.

PALScan

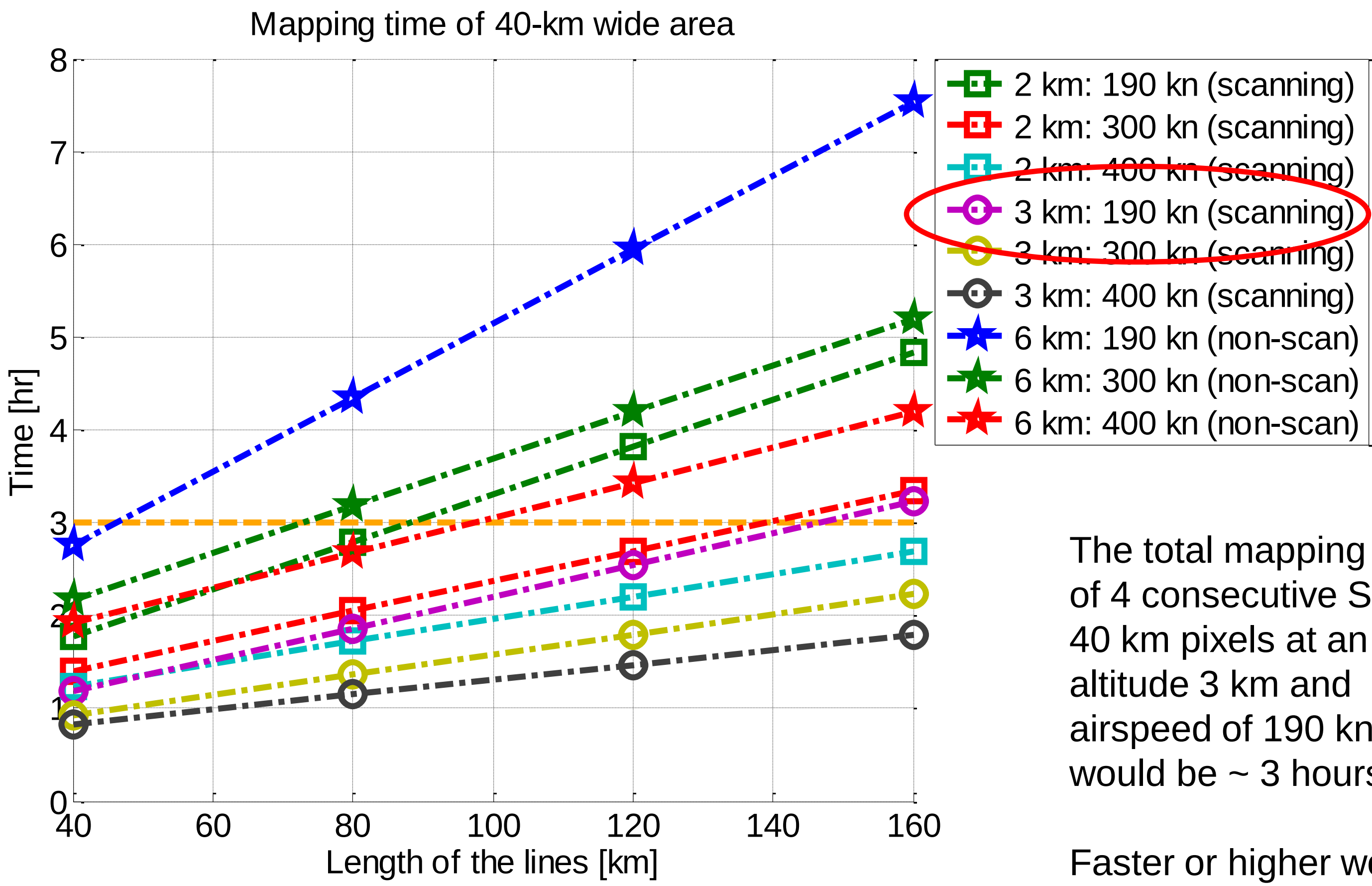






- In order to decrease the impact of the noise in the measurement several measurement samples are averaged together.
- In order to determine how many measurement samples are available for averaging the scanning was simulated over a hypothetical grid.
- The grid cell size is set to half of the effective footprint (effective footprint is determined as the square root of the area captured within the 3dB beam width).
- It is desirable that the cell size is smaller than the footprint in order not to degrade the effective spatial resolution too much. The left-hand figure shows the result of the simulation.
- The number of samples per grid cell increases toward the edges of the swath due to the overlapping scans (Figure 4) and the minimum is found at the center of the swath as shown by the middle figure.
- The required noise performance is application dependent. For soil moisture measurements noise level of about 0.5 K per pixel is acceptable.
- Considering the noise level in PALS (NEDT about 1 K without additional integration with the current sampling scheme) averaging of about four samples is required to meet this requirement.
- Right-hand figure shows that the noise performance in high-speed low altitude flight comes close to this requirement but in other flight options the requirement is met with a margin.

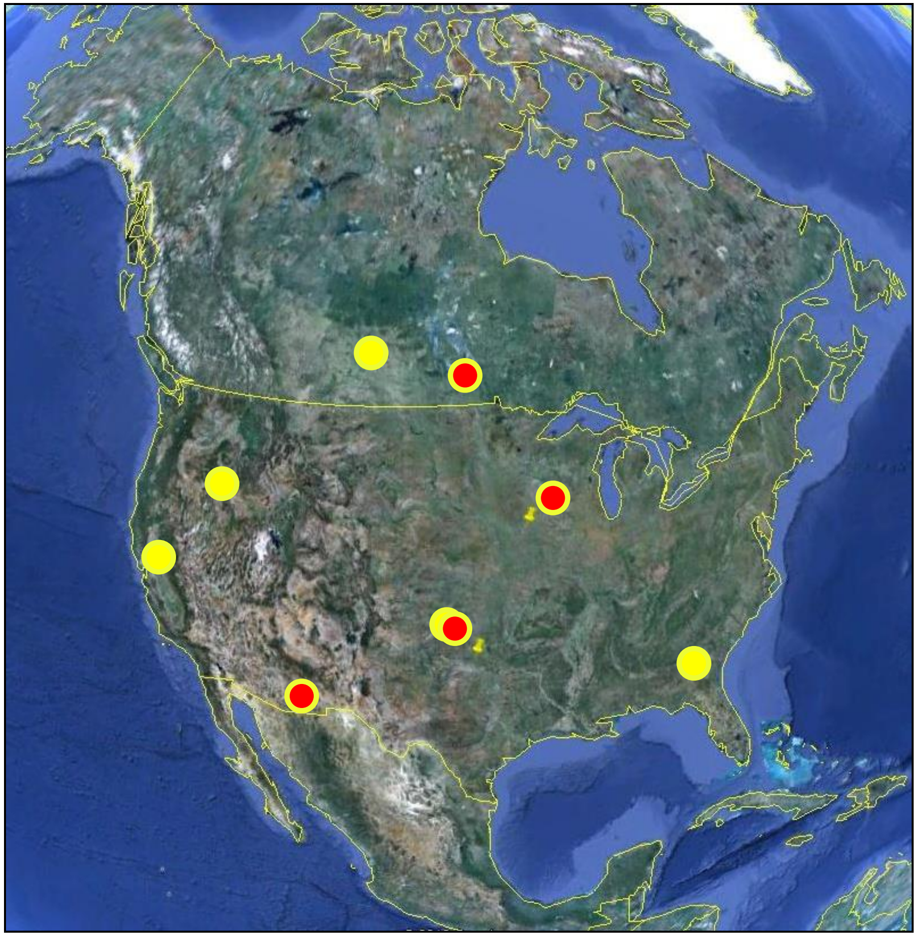
PALScan



The total mapping time of 4 consecutive SMAP 40 km pixels at an altitude 3 km and airspeed of 190 kn would be ~ 3 hours!

Faster or higher would provide more spatial coverage or reduce mission time.

Post-Launch SMAPVEX16: Where?



	OK	MB	AZ	IA
Infrastructure	M	H	H	L
Vegetation Range	M	H	L	H
SM Range	H	H	M	H
Seasonal Limitations	M	M	L	M
Cost Sharing	L	H	L	L
Heritage	H	H	H	L

SMAPVEX16 Discussion

- Are we OK with general concept?
- Any other science arguments for/against 2016?
- Thoughts on sites
- Canadian commitment?
- Any other aircraft options?
- Creative ideas on aircraft calibration?