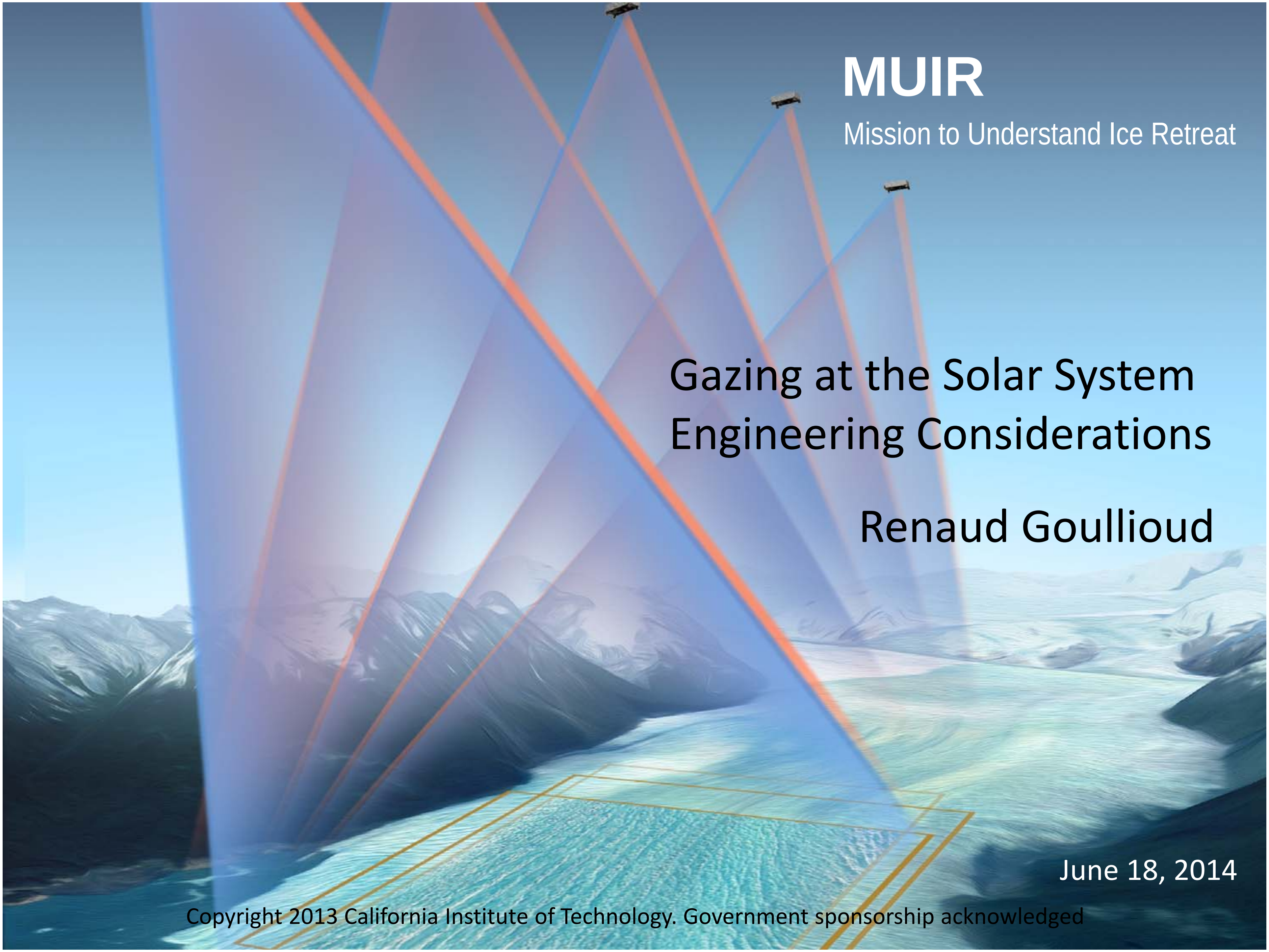

MUIR

Mission to Understand Ice Retreat

Gazing at the Solar System
Engineering Considerations

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Topics

Randomly:

- Earth Venture proposal experience.
- The requirement flow-down.
- The Science Traceability Metrics.
- Understanding the limitations.
- Next steps.

Introduction

- The Mission to Understand Ice Retreat proposal was developed by Andrea’s team for the Earth Venture Instrument 2 call.
- The Proposal was not submitted because we were not ready for this call.
- Next two calls in the 12-18 months time frame.
- This is a competitive call, only the best proposal (in all aspects) is going to be selected.
- We were not ready in many aspects.

Science case

- *What fraction of glacier mass loss is driven by solar radiation?*
- *Determine how albedo drives ice loss*
- *MUIR simultaneously measures mass change and albedo*

- The science case was initially well received
- Is it strong enough in light of the competition?
- Free telescope time can be used for additional science, how to get credit for that without making the story to confusing.

Science Requirements

- Compelling science requirements is not sufficient.
- Need to convert science case into hypothesis and model.
- Define what parameters need to be determined through the science mission.
- Quantify how well you need to measure the experimental parameters to meet your science objectives.
- The cleaner the objective->experimental measurement story, the stronger the proposal.
- A model of the science experiment or even better experimental results from a similar (flight/airborne) experiment are key to build the case.
- Ideally, we can generate key sensitivity for driving requirements: volume error vs vertical resolution,…

Developing a model to flow requirements

Conservation of Energy and Mass

Terms

- ΔE_S = Absorbed solar energy
- ΔM = Total mass change
  - ΔM_M = Mass lost from melting
  - ΔM_O = All other sources of mass (precipitation, mass wasting, etc.)
- L = latent heat of melting ice

- $\Delta M = \Delta M_M + \Delta M_O$ (total mass lost)
- $\Delta M_M = \Delta E_S / L$ (amount of ice melted from absorbed solar energy)
- $\Delta M_O = \Delta M - \Delta E_S / L$ (compute mass lost from other sources)
- $\Delta M_M / \Delta M_O$ (Fraction of mass lost from absorbed solar energy)

MUIR measures $\mathbf{\Delta E_S}$ and **ΔM** for *hundreds* of glaciers

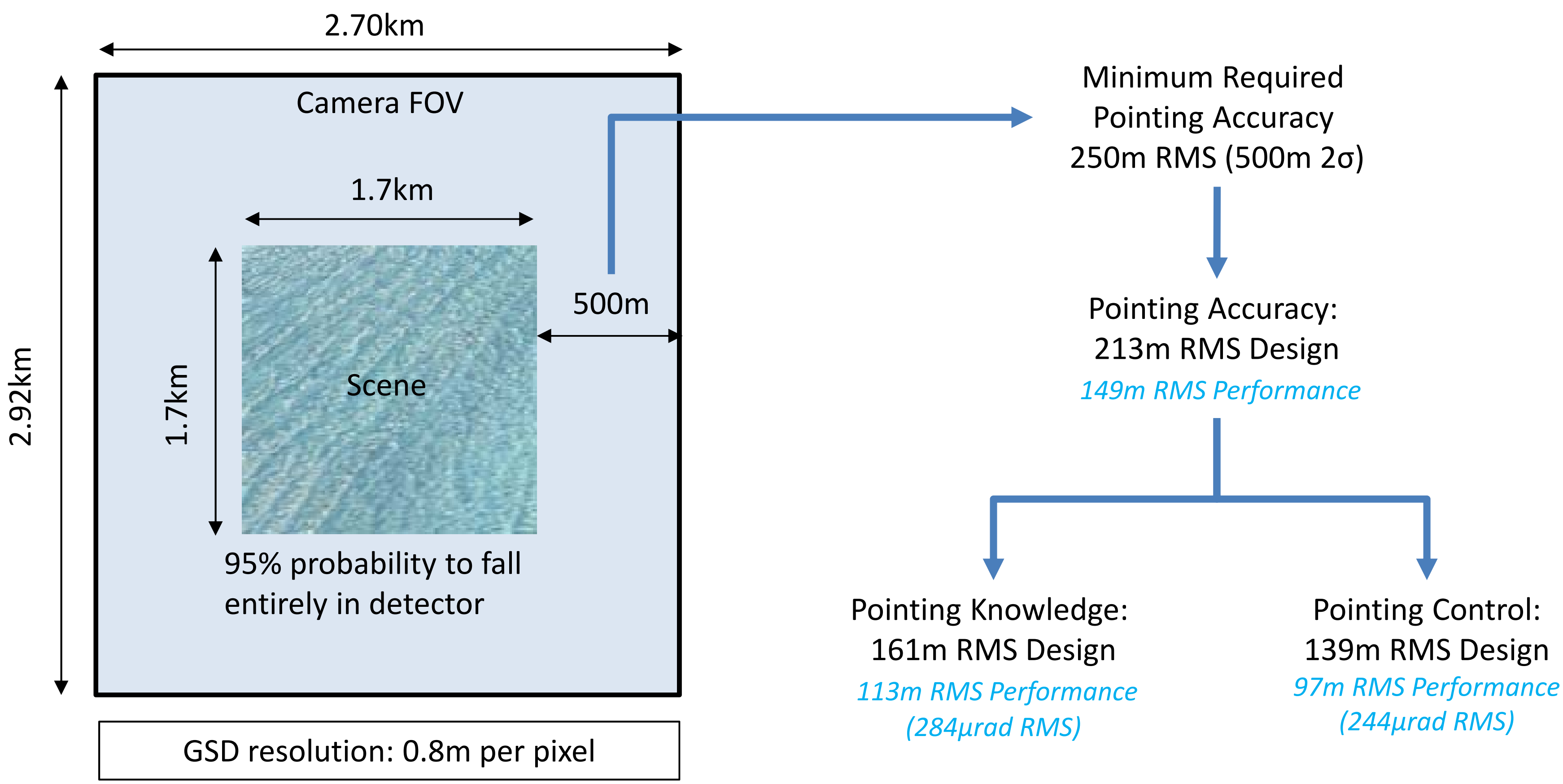
The Science Traceability Matrix

Science Requirements							
Science Goals	Science Objectives	Science Measurement Requirements Observables (function of time)	Science Measurement Requirements Physical Parameters	Instrument Requirements		Projected Performance	Mission Requirements (Top Level)
Determine the fraction of glacier mass loss driven by solar radiation	Determine glacier mass balance variability	Glacier extent (M1)	Georectified coregistered imagery (P1)	Targets	≥396 quarterly	727 quarterly	Mountain glaciers
				Single image resolution	1 m/pixel nadir ground scale	80 cm diffraction limited resolution	3 year mission
				Combined images resolution	50 cm (post-processed)	30 cm (post-processed)	Tie points in image
							Geolocated context imagery
				Field of view	≥ 1 km at nadir	1.9 x 2 km at nadir	Sub-seasonal sampling
		Flow rates (M2)	Correlated changes between passes (P2)	Group motion of features	30 cm/pair	10 cm/pair	≥4 passes of observations /target/year
		Glacier surface shape (M3)	Digital Elevation Models (DEMs) (P4)	Vertical resolution	50 cm (post-processed)	35 cm (post-processed/pixel)	Staring capability
				Field of regard	50° radius cone around nadir	60° along/ 50° cross track at nadir	
				Pointing control knowledge accuracy jitter	At nadir 100 m 150 m 250 m 50 cm	At nadir 97 m 113 m 214 m 38 cm	Variable illumination Non-sun synchronous orbit
			Bidirectional reflectance distribution function (BRDF) (P5)	Views per pass	≥10 each color	10-95 each color	
	Determine solar energy input to glaciers	Albedo (M4)		Reflectance (scene average)	SNR ≥100	SNR 100–170	
			Multispectral (P6)	Color	Blue, green, red, NIR	487, 562, 660, 835 nm	Filter wheel
			Integrated BRDF over all angles (P7)	Accuracy	2%	1%	Monochromatic imagery

Mission/Instrument Requirements

- Once the science requirements are established and justified, we need to develop the Mission and Instrument requirements.
- Again a mission/instrument model showing how the science requirements can be met for a set of instrument parameters.

Pointing accuracy and field of view



Imaging resolution error budget

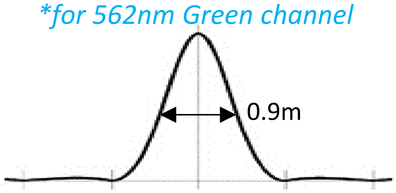
Stereo-Imaging (30 views over 100°)
Vertical Height Resolution
0.70m Design
0.55m Performance

Horizontal Resolution at nadir
1.45m Design (1.82pix)
1.14m Performance (1.42pix)

RSS

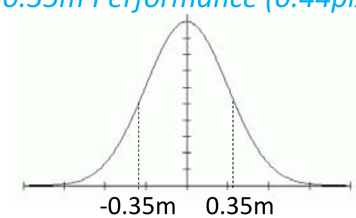
x2

Diffraction FWHM (λ/D)
1.06m Design (1.33pix)
0.9m Performance (1.13pix)*
**for 562nm Green channel*

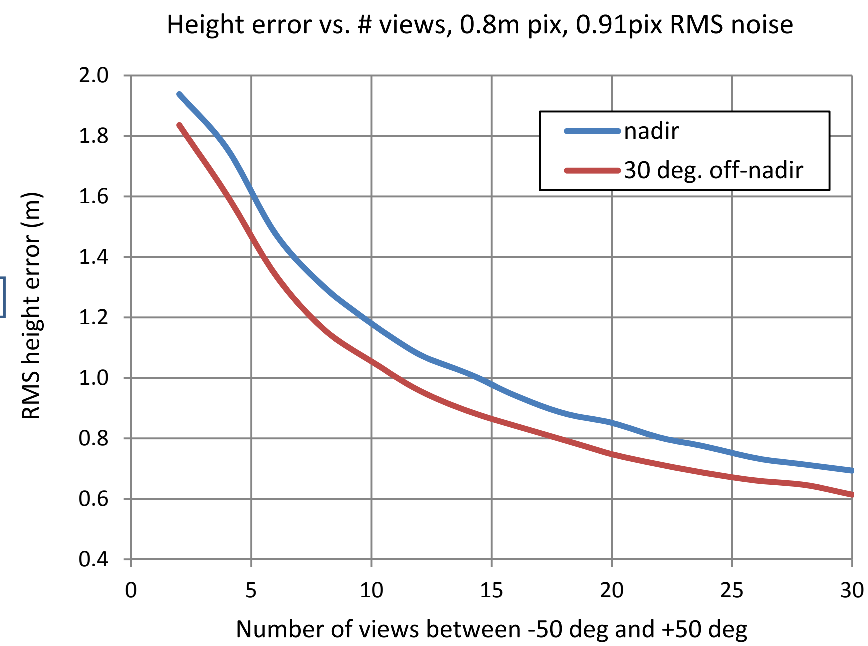


Diffraction (25cm aperture)

Pointing Jitter one sigma
0.50m Design (0.63pix)
0.35m Performance (0.44pix)



Pointing jitter (20ms)



EVI-2 Lessons-learned

- Started by an instrument of similar size as SkySat1.
- Develop science/mission/instrument requirements.
- Concluded that the instrument had to be significantly increased to meet the requirements.
- However: **"Who believe we cannot do game changing science with a dedicated SkySat1-like satellite?"**
- We need to start the requirement definition/validation process very early to get a chance to iterate.

The limitation for glaciers

- Super-resolution:
  - Can beat down optical aberration, under-sampling.
  - Works well with high contrast scene, high SNR data.
  - Cannot compensate for diffraction limitations.
  - Does not work well with low contrast scene, low SNR data.
- 3D reconstruction:
  - Accuracy increase with angle diversity.
  - Need features and texture to build the DEM.
  - Features and texture need to be well contrasted.
  - Features and texture vary with viewing angles.
  - Features and texture can vary significantly from visit to re-visit.

The limitation for short events in process

- Staring imaging is time expensive: ~5 minutes repointing for 5 minutes staring.
- For an optimized schedule the number of observations is likely no more than 4 observations per orbit.
- Taking into account land surface, S/C downtime, cloud coverage, the mission efficiency is likely less than 20 observations per day.
- Establishing a science case around observing short, rare, unpredictable event (landslide, avalanches) is not credible.

Conclusion

- We learned a lot from the EV2 proposal experience.
- There is a clear interest/need for this type of Space instrument.
- We are a lot better off than one year ago.
- The collaboration with SkyBox1 can go a long way to help us.
- Glacier data and algorithms exist to build the foundation for a strong proposal.
- We need to start the requirement process and the mission definition as early as possible.