Interim Report of the COMS INR Performance Enhancement through the 1st Four Years of Normal Operation

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9~13 Nov, 2015, Tokyo, Japan
The 6th Asia/Oceania Meteorological Satellite Users' Conference

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Background (1): COMS

COMS (Communication, Ocean and Meteorological Satellite)
: Geostationary, multi-mission* satellite

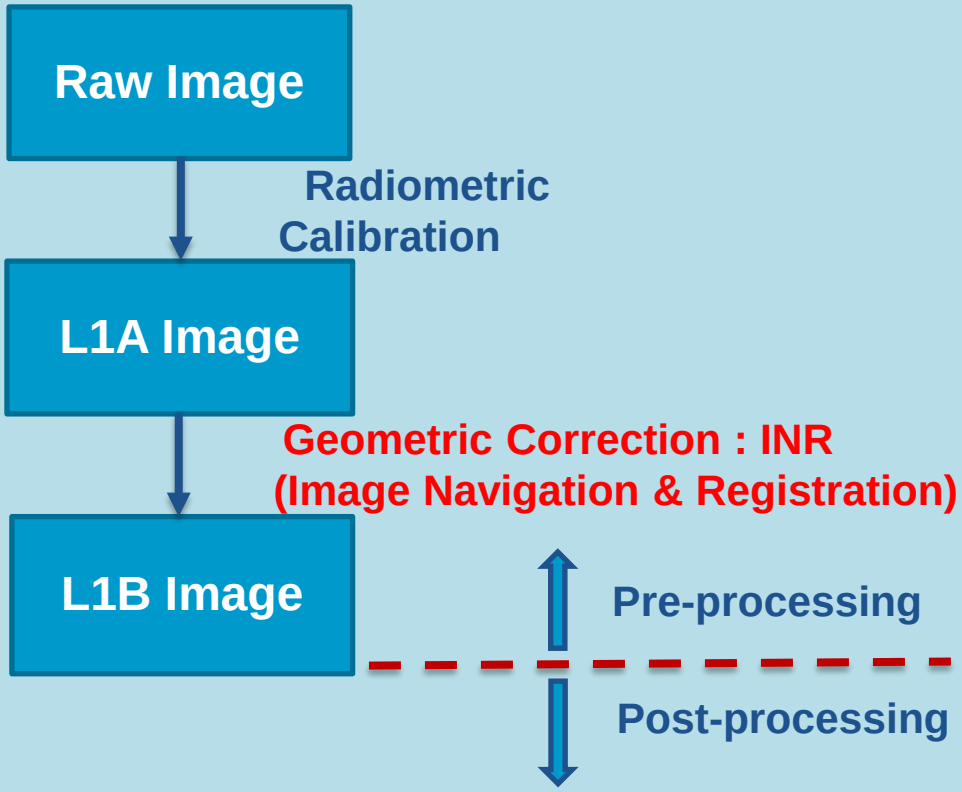
<u>*COMS Missions</u>
A meteorological mission (MI: Meteorological Imager)
An ocean imager mission (GOCI: Geostationary Ocean Color Imager)
An experimental Ka band telecommunication mission

Mass at Launch: 2460 kg
Power : > 2.5 KW (@ EOL)
Orbital Location: 128.2^{o}E
Operational Life time: 7.7 years, Design Life time: 10 years

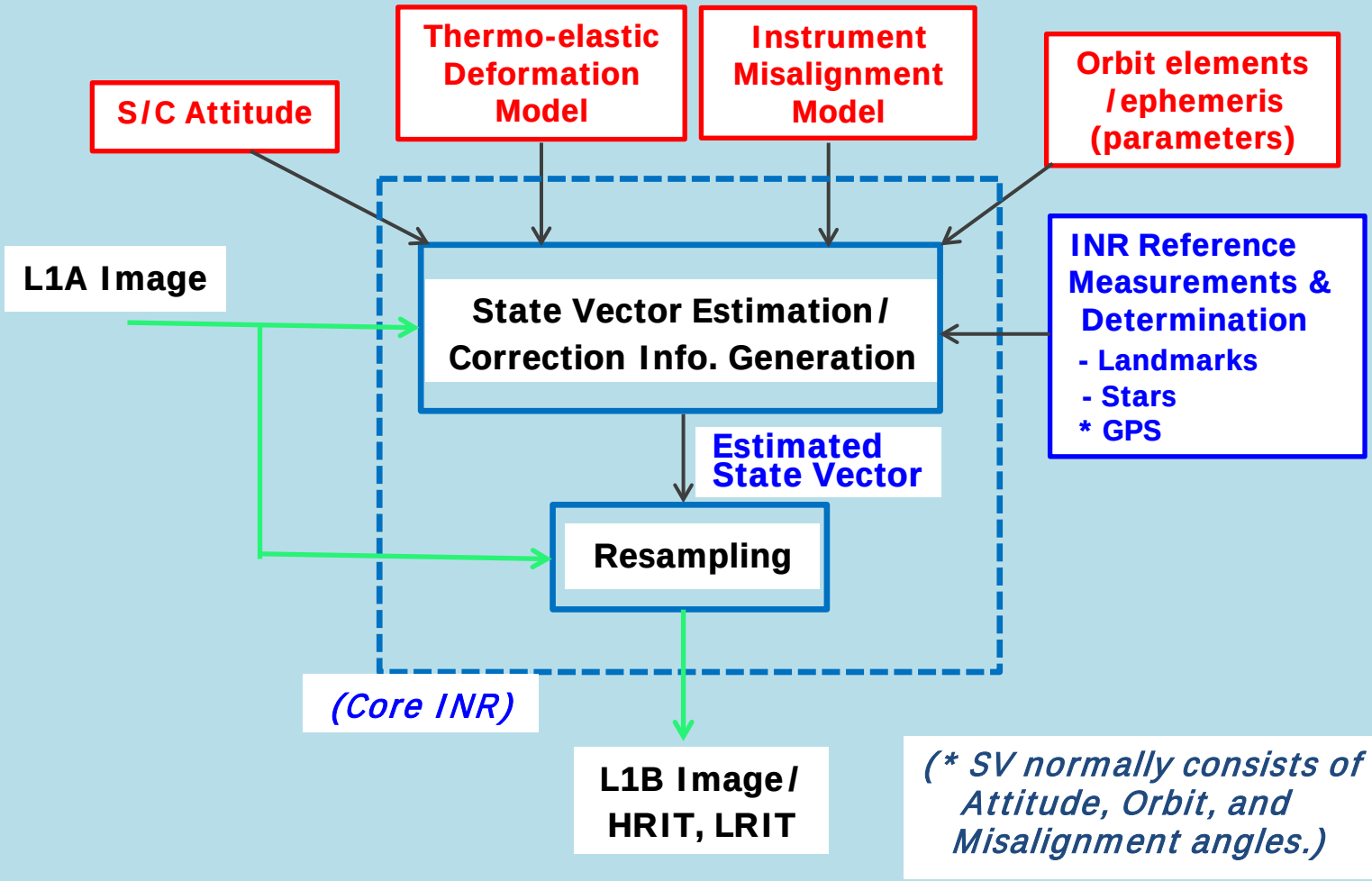
Launched @ June 26, 2010, 21:41 (UTC) by Ariane 5 ECA

Background (2): Image Processing

“Image” :



Background (3): INR (in a Nutshell)



Background (4): Evolution & Comparison of INR Systems

	Estimation algorithm	Timeliness	Reference measurements	Function (processing) allocation	Req. Spec. (& Typical performances)		
					Absolute Nav. Error (3 σ)	F2F Registration 15 Minuets (3 σ)	Co-registration (3 σ)
GOES I~M	A priori Least Square	Timeliness: 0.7 minutes from start of image	Landmarks + Imager Stars	On-board + Ground	**112 μrad**	42 μrad	Vis to IR: 50μrad IR to IR: 28μrad
GOES N~P	A priori Least Square	Timeliness: 0.7 minutes from start of image	Landmarks + Imager Stars	On-board + Ground	**56 μrad**	28 μrad	Vis to IR: 50μrad IR to IR: 28μrad
MTSAT-1R	A priori Least Square	Timeliness: 3 minutes from start of image	Landmarks + Imager Stars	Ground processing	Vis: Vis pixel IR: IR pixel (rms)	25 μrad (rms)	IR to IR: ±0.1 IR pixel (rms)
MTSAT-2	A priori Least Square	Timeliness: 3 minutes from start of image	**Landmarks**	Ground processing	Vis: Vis pixel IR: IR pixel (rms)	25 μrad (rms)	IR to IR: ±0.1 IR pixel
COMS	*A posteriori Least Square*	**Timeliness: 12 Minutes from end of Image**	**Landmarks**	Ground processing	**56 μrad**	28 μrad	Vis to IR: 50μrad IR to IR: 28μrad
GOES-R	Kalman filter	Timeliness: Near real time	Imager Stars + GPS	On-board + Ground	**21 μrad**	16 μrad	6 μrad

Motivation

- **Let us improve**
  ‘COMS INR operational performances’:

  - centered around the ‘timeliness’ performance
  - dissect and identify the good, the bad, and the ugly in COMS INR design
  - maintain/expand the good, improve/replace the bad, and clean up/simplify/discard the ugly
  - see if we can enhance other INR performance metrics alongside

Summary of the Efforts (1)

‘Delta INRSM’

“Improved version of COMS INRSM* in timeliness and potentially in INR performance metric as well, by replacing the least squares with Kalman filter and by ensuring all the interfaces and ops cond.”

*INRSM (INR Software Module)

Summary of the Efforts (2)

- **Delta INRSM development log**

  - Revisit of COMS INR design and feasibility study on the reusability of COMS INR algorithm for the future (2011. 10. 1 ~ 2012. 4. 30)

  - COMS INR Kalman filter Algorithm (CIKA) development (2011. 10. 1 ~ 2012. 4. 30)

  - COMS INR Simulator development (2013. 1. 21 ~ 2013. 7. 20)

  - CIKA refinement & optimization for the implementation into COMS INRSM (2013. 8. 21 ~ 2013. 12. 30)

  - Delta INRSM implementation (2013. 12. 21 ~ current)

Summary of the Efforts (3)

- **Key Objectives in Delta INRSM development**

  - Maximal re-use of COMS INRSM's 'good' heritage (Landmark Determination, Navigation Equation, Re-sampling) in documentation, source code, database

  - Replacement of Least Squares by Kalman filter

  - Minimum change of algorithm and coding from the operational INRSM

  - Aim for performance enhancement in the timeliness

  - Aim for a more consistent and potentially improved navigation/registration performances

  - Aim for an overall framework of generic, standardized INR system development, validation and operation

Key Results and Implications (1)

Summary of the current outcome and the overall status

	Timeliness* (min.)						Navigation Error (EW/NS) (μrad, 3-sigma)					
	FD		ENH		LA		FD		ENH		LA	
INRSM**	Wait	No-Wait	Wait	No-Wait	Wait	No-Wait	Wait	No-Wait	Wait	No-Wait	Wait	No-Wait
	10:25	**3:02**	9:41	**2:35**	9:16	**1:57**	54.5/52.5	42.9/41.2	52.4/50.6	41.3/39.4	47.2/40.0	34.8/25.8
INRSM-r***	Wait	No-Wait	Wait	No-Wait	Wait	No-Wait	Wait	No-Wait	Wait	No-Wait	Wait	No-Wait
	(? TBC)											
Delta INRSM******	**1:44** (r=0.1) ☜ **1:59** (r=0.14)		**1:50** (r=0.1) **1:57** (r=0.14)		**1:04** (r=0.1) **1:26** (r=0.14)		**28.9/25.0** (r=0.1) **28.6/24.5** (r=0.14)		**28.9/25.0** (r=0.1) **28.6/24.5** (r=0.14)		**28.9/25.0** (r=0.1) **28.6/24.5** (r=0.14)	

*: as per timeliness definition of COMS req. spec.

**: courtesy of KMA test/analysis result (72hrs data)

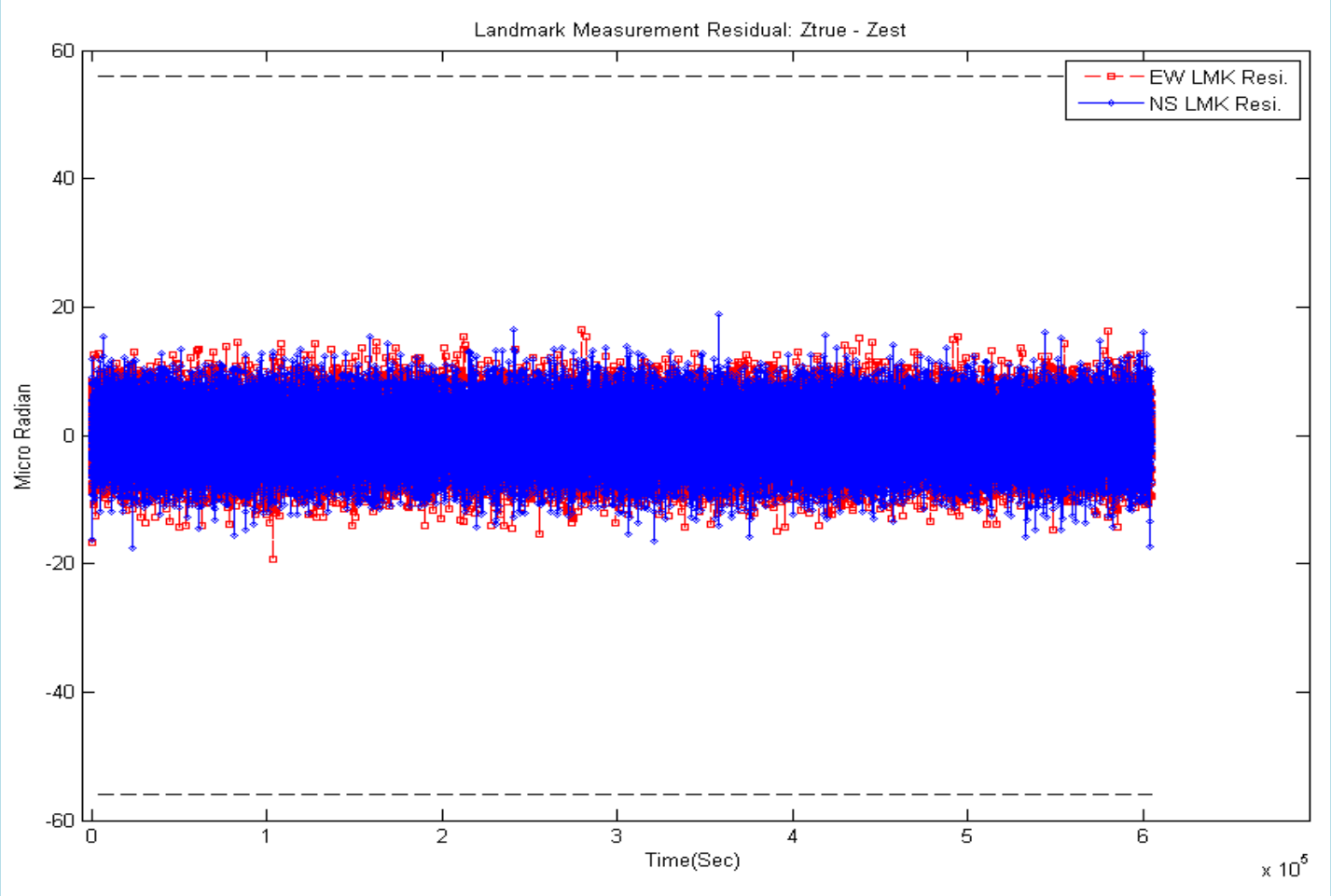
***: courtesy of Satreci test/analysis result

****: courtesy of KARI test results (backup real-time system in KARI GS)

☜ : r='landmark reliability' (minimum reliability)

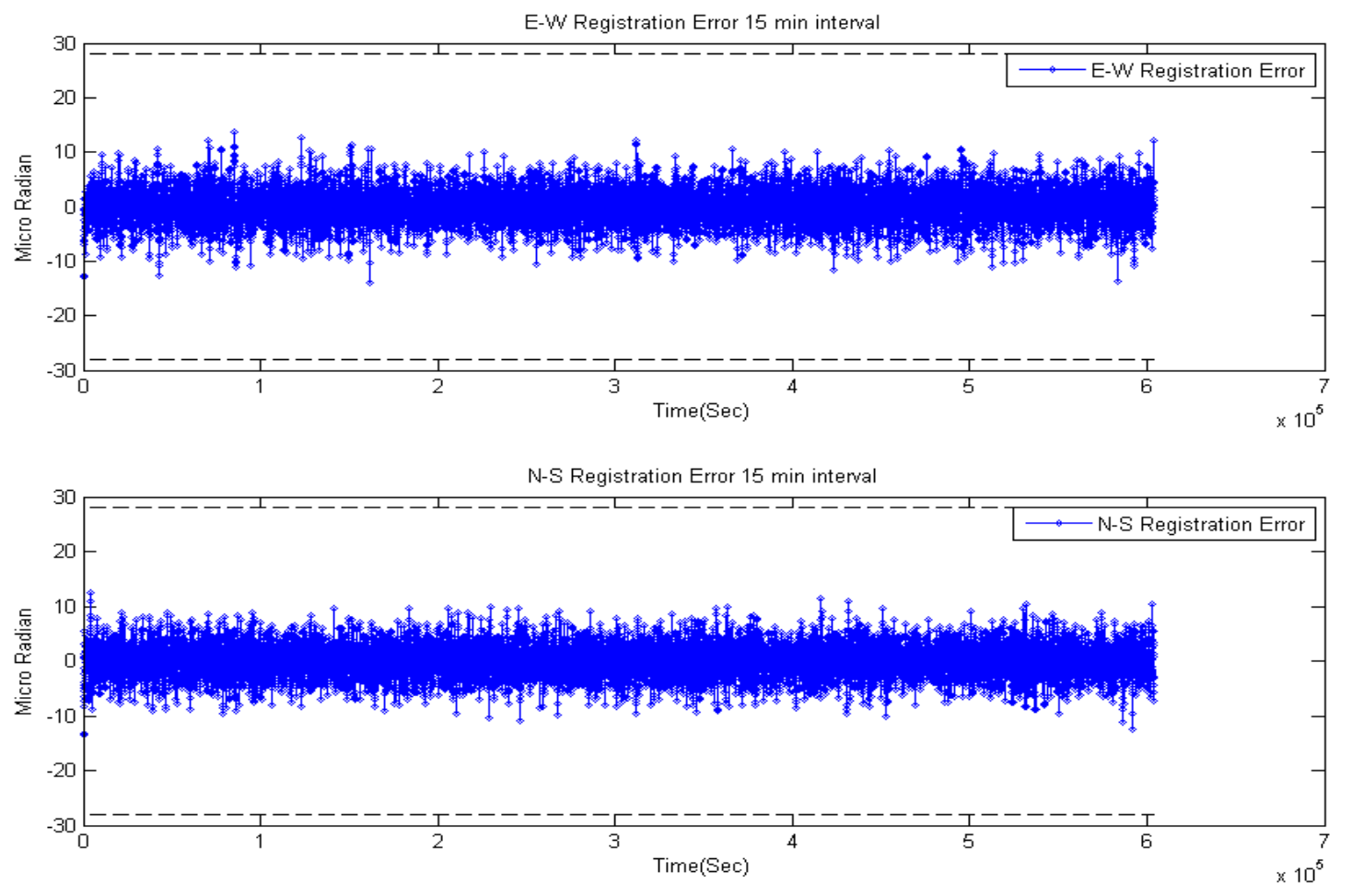
Key Results and Implications (2)

Simulation result (1) – *Residual (Navigation Error)*



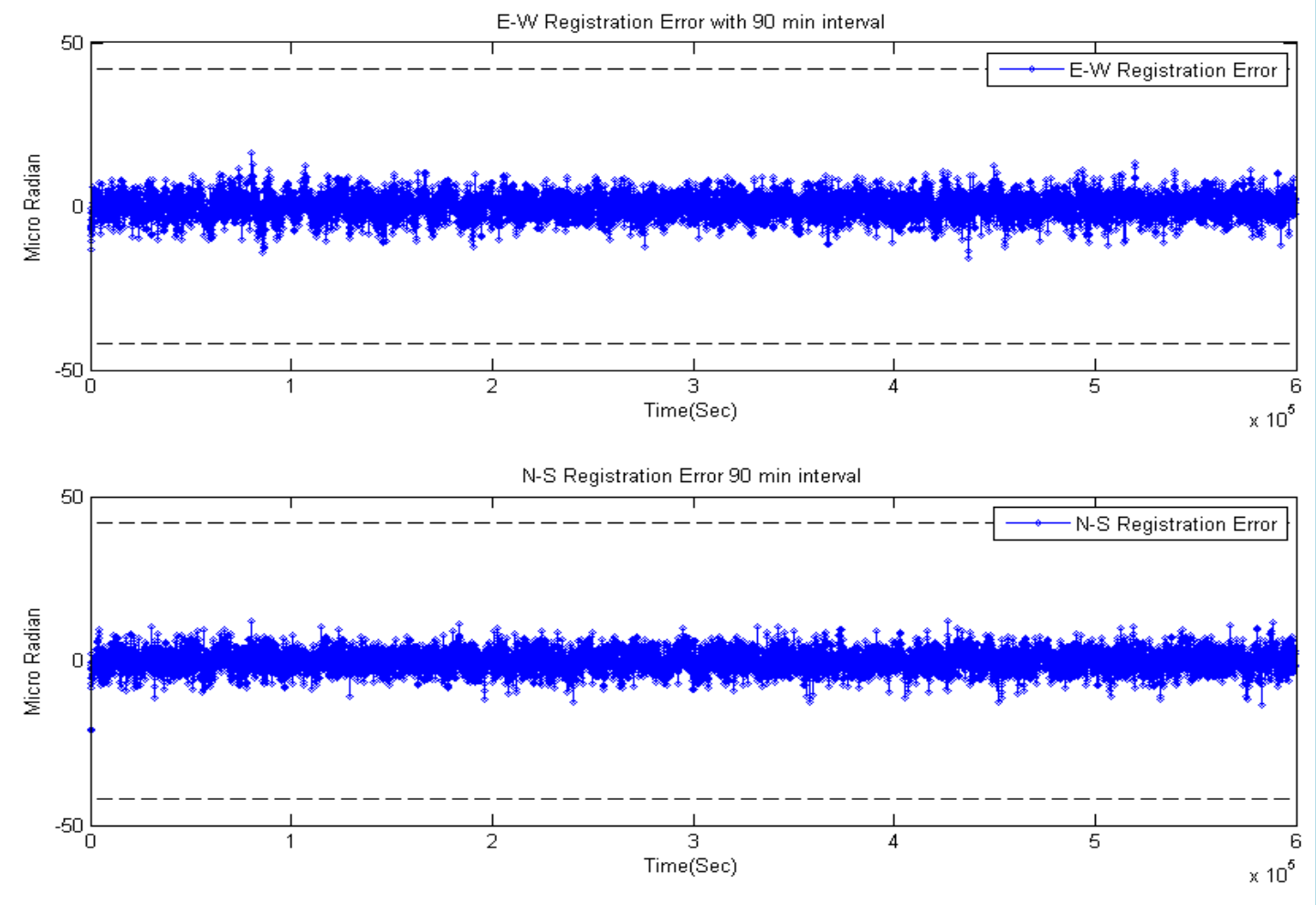
Key Results and Implications (3)

Simulation result (2) – *Registraion Error (15 min, f2f)*



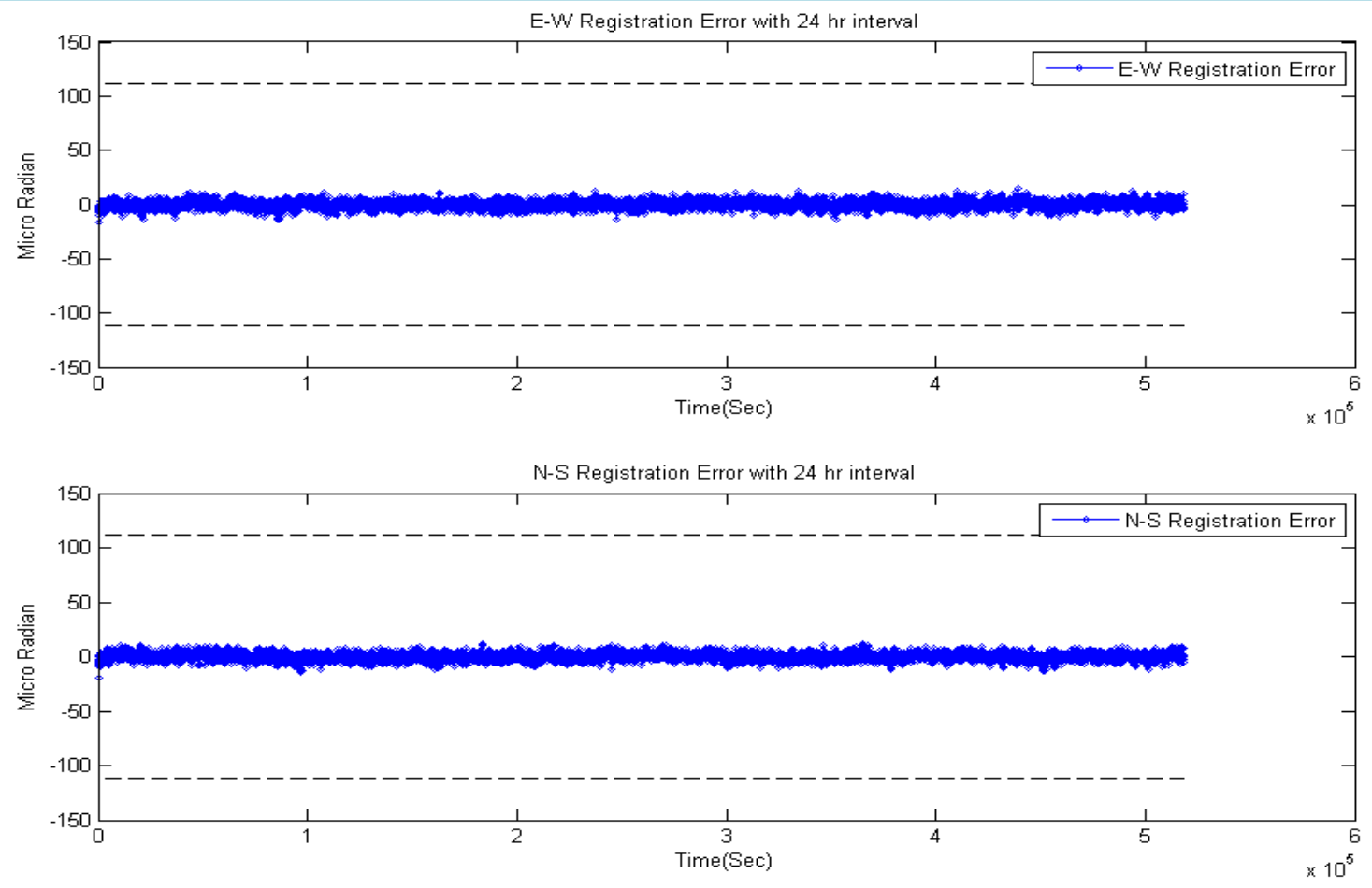
Key Results and Implications (4)

Simulation result (3) – *Registraion Error (90 min, f2f)*



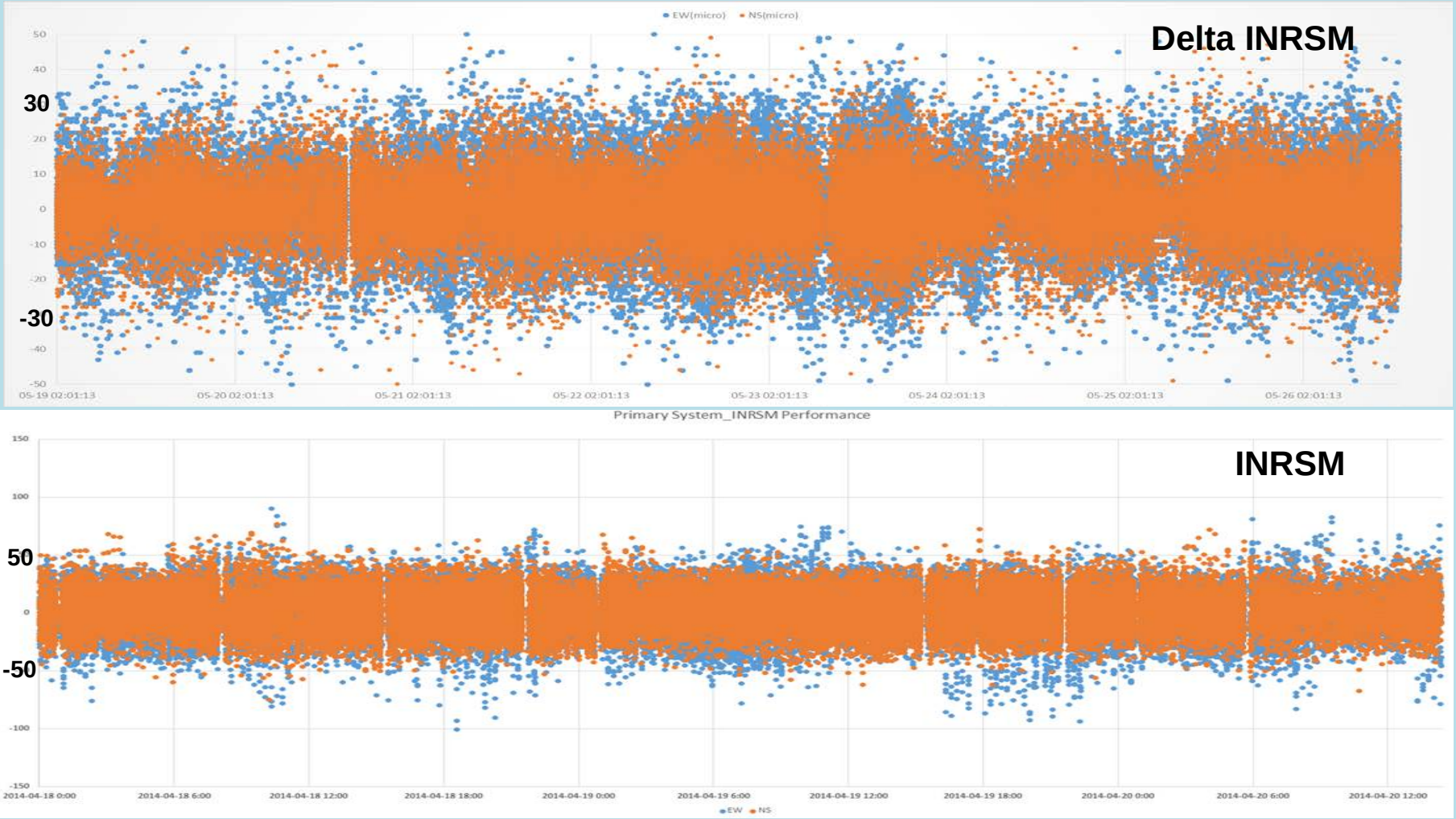
Key Results and Implications (5)

Simulation result (4) – *Registraion Error (24hr, f2f)*



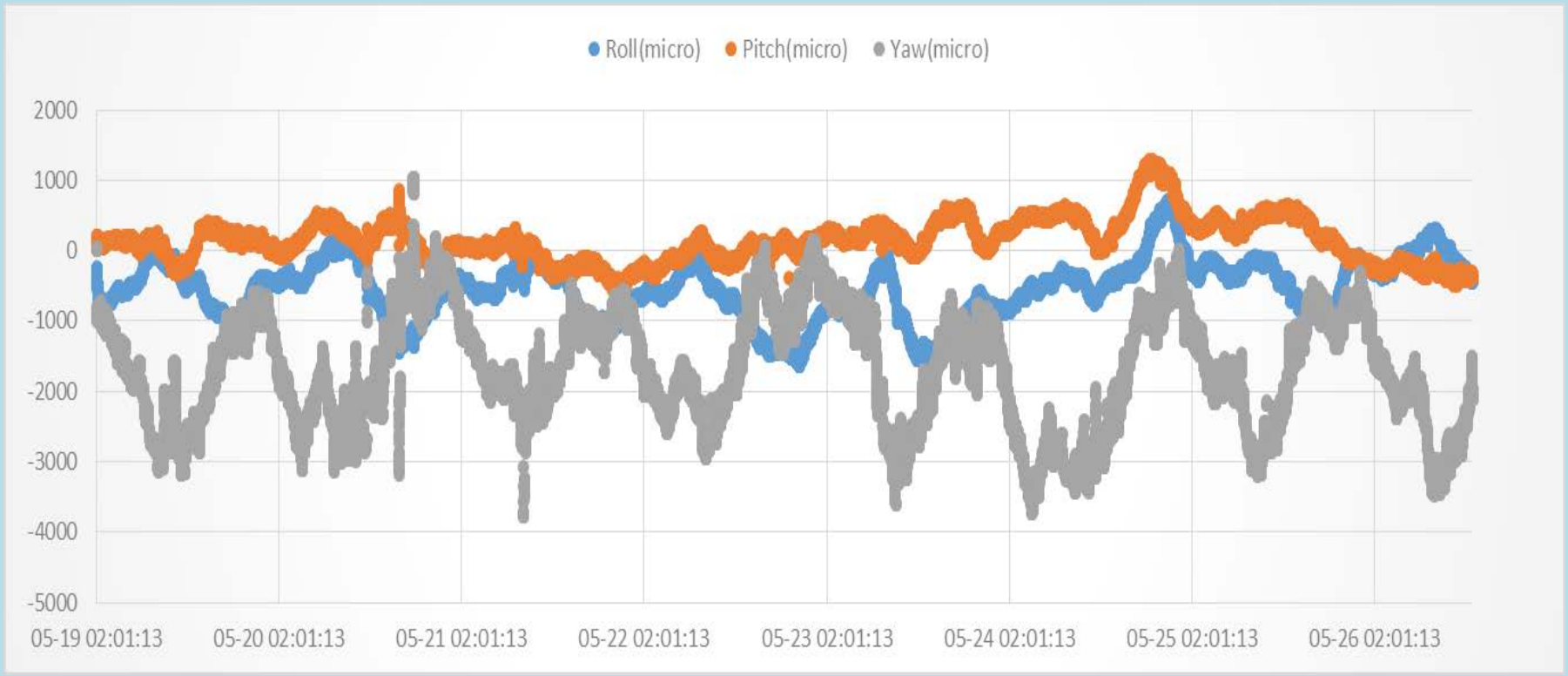
Key Results and Implications (6)

Delta INRSM (vs) INRSM – *Residual (Navigation Error)*



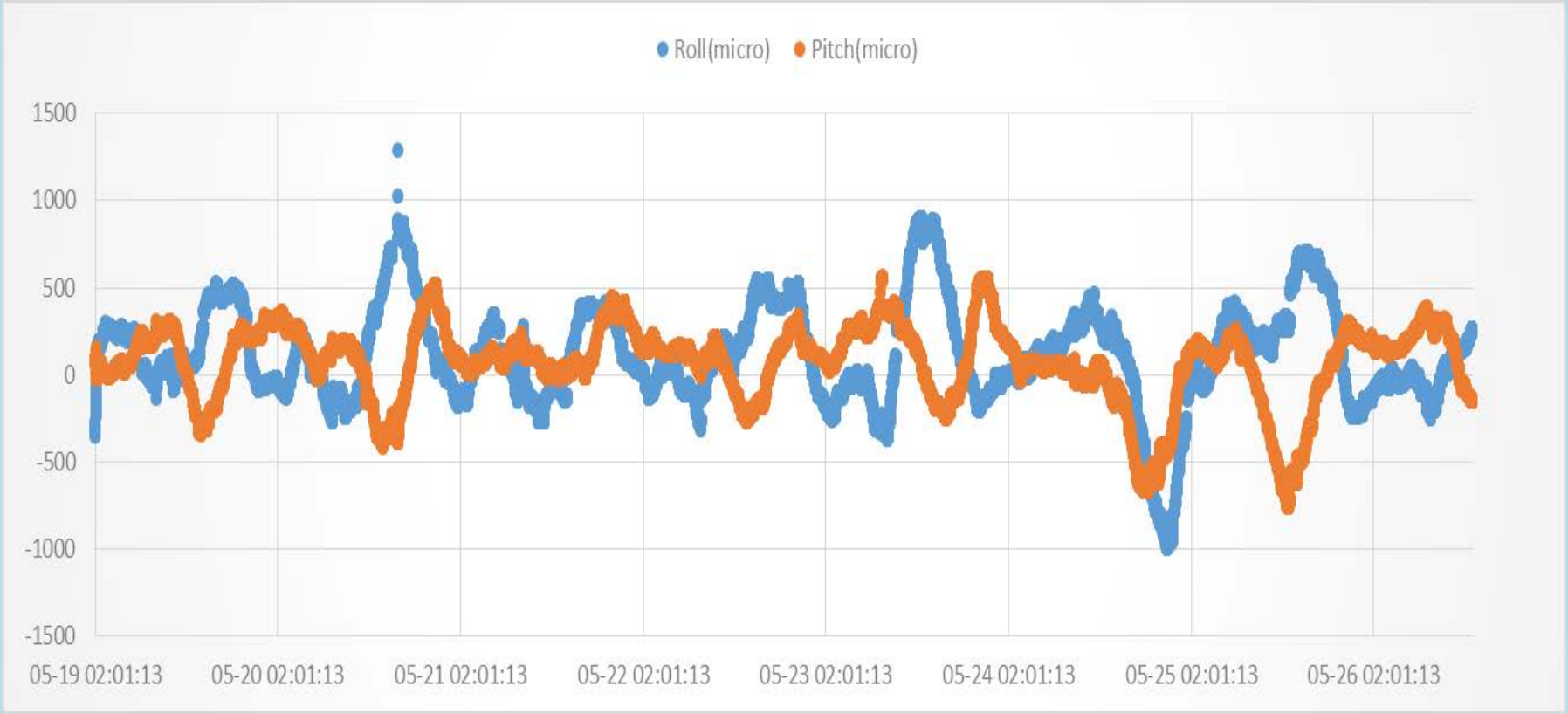
Key Results and Implications (7)

Delta INRSM: *CorrAngles*



Key Results and Implications (8)

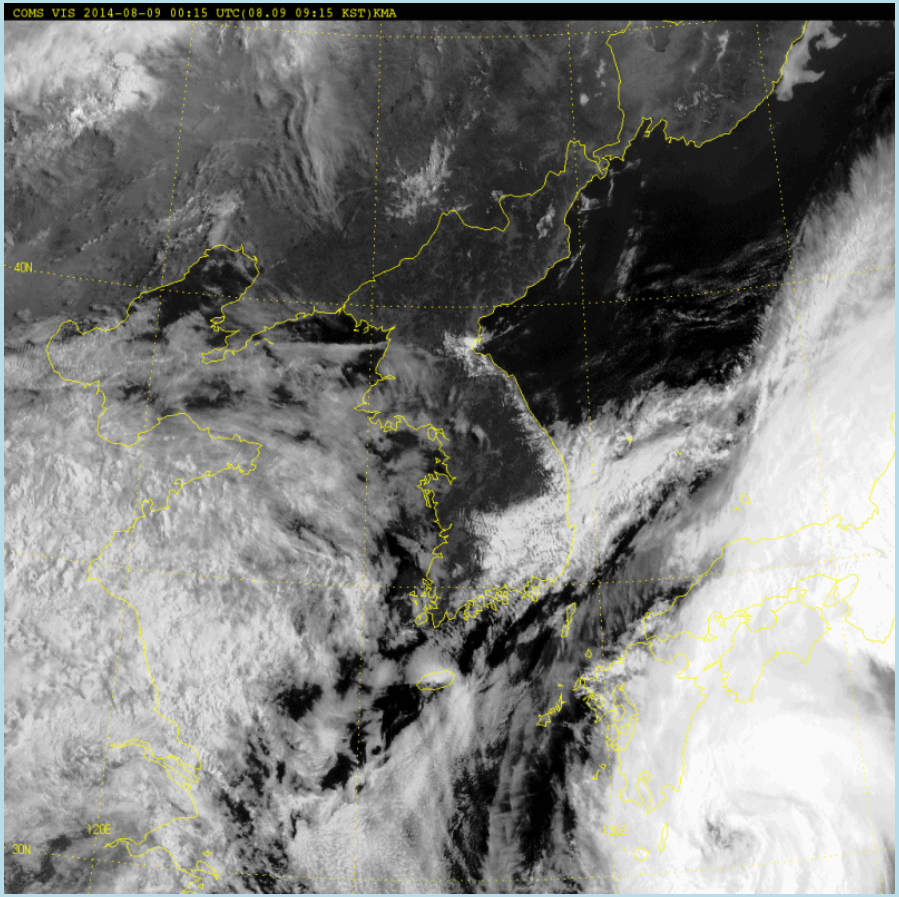
Delta INRSM: *Misalignment*



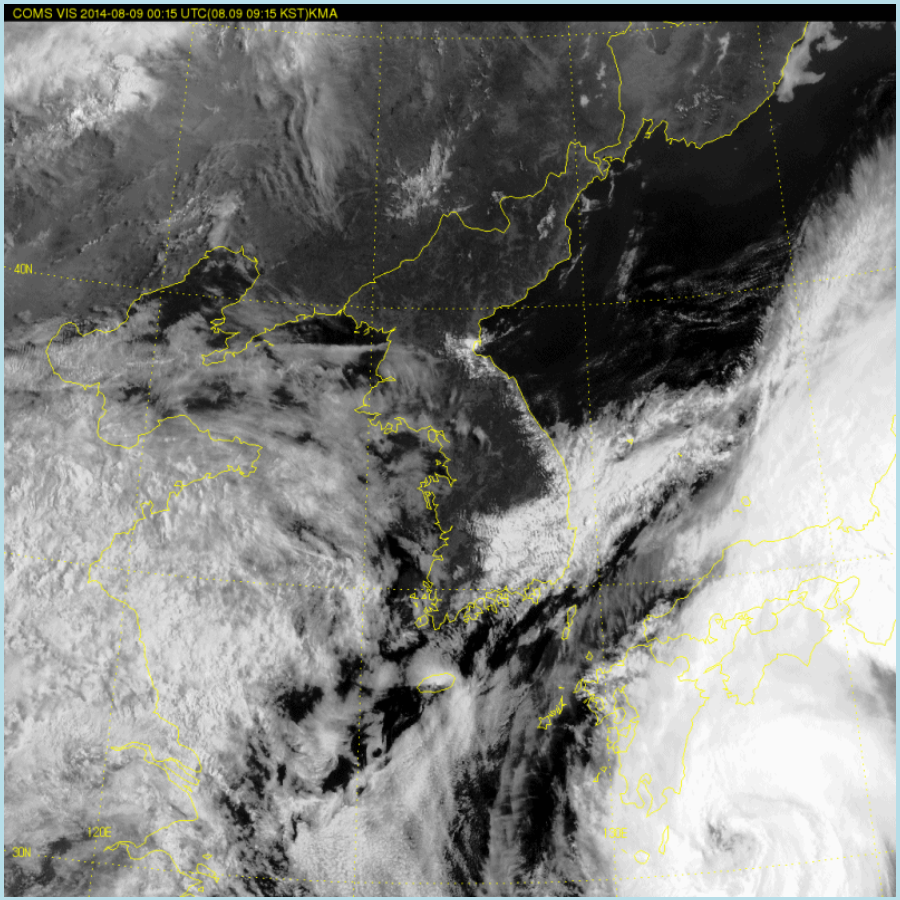
Key Results and Implications (9)

Delta INRSM Sample Test Result :

(2014-08-08 ~ 2014-08-10, r=0.13)



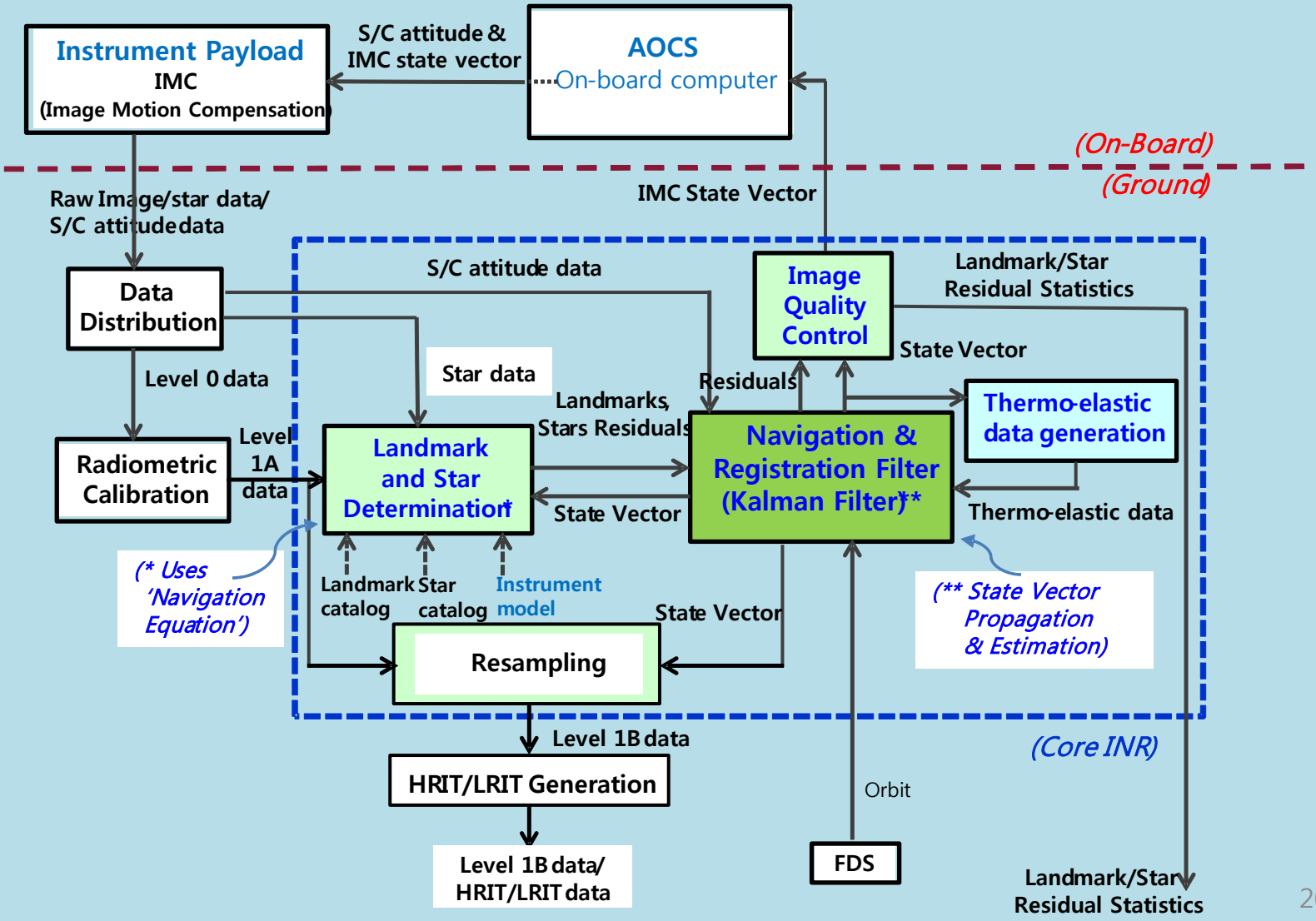
Primary (INRSM)



Delta-INRSM

Key Results and Implications (10)

Generic INR Architecture



Conclusion & Suggestion

- **COMS INR performance enhancement is pursued and being achieved for the enhancement of COMS MI data application and utility to its maximal capability, for the remainder of COMS MI mission operation, and also as the preparation for the follow-on missions.**

- **A foundation for the expansion of INR technologies is established, by systemizing the technical findings, breakthroughs and lessons obtained through this work.**

- ***'Chopstick culture' and regional collaboration:***
  "In the grand scheme, it is the time to call for more proactive collaborations among nations in this region, not only in the user perspectives but also in the development aspects." (re-quote from AOMSUC-3)