Orbit Determination using Two way measurements and Extended Ephemeris of NavIC Satellites

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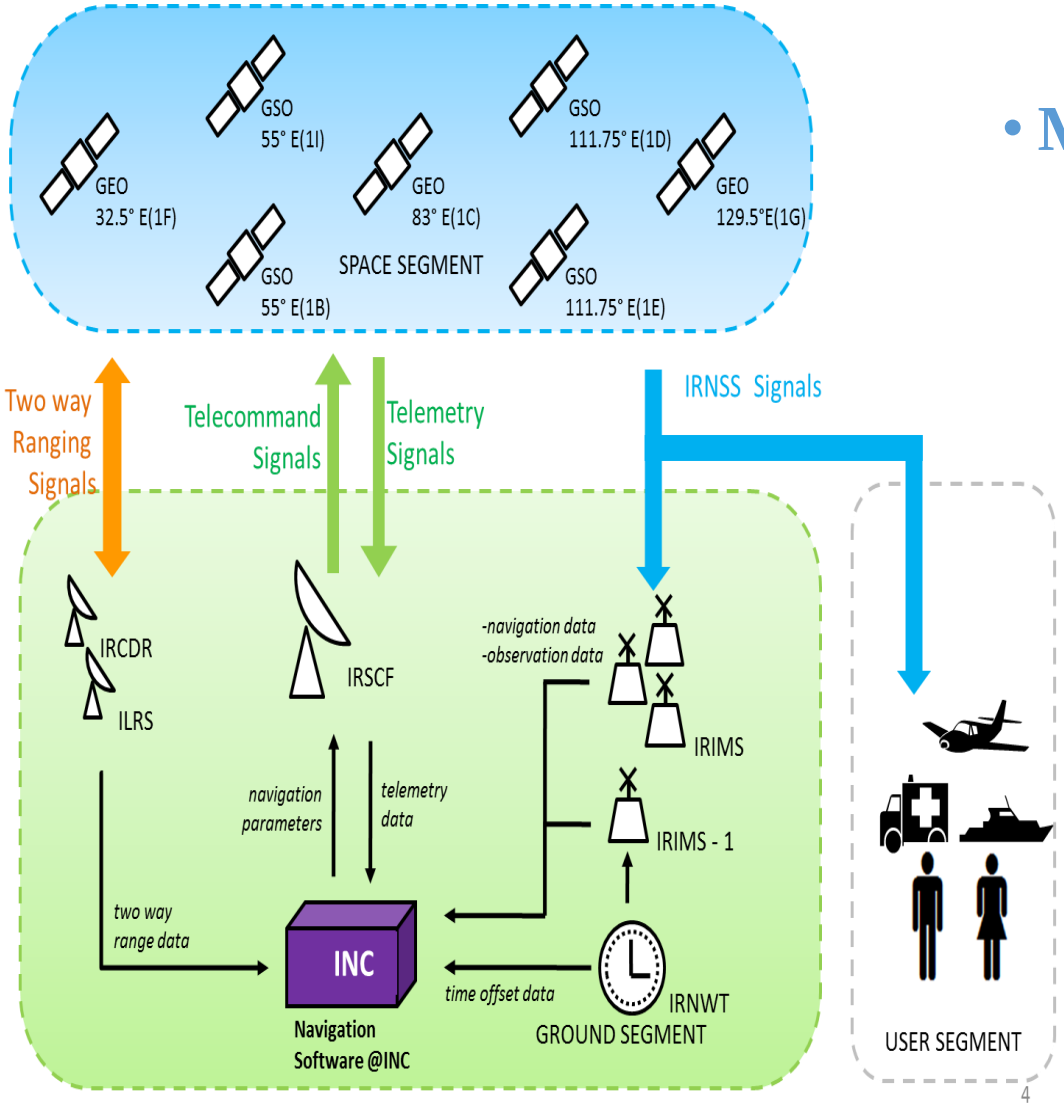
Introduction To NavIC System

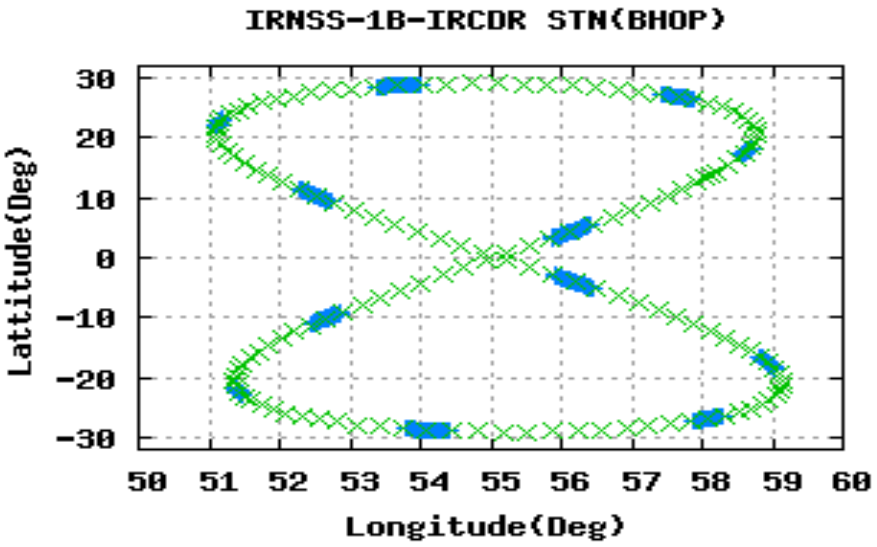


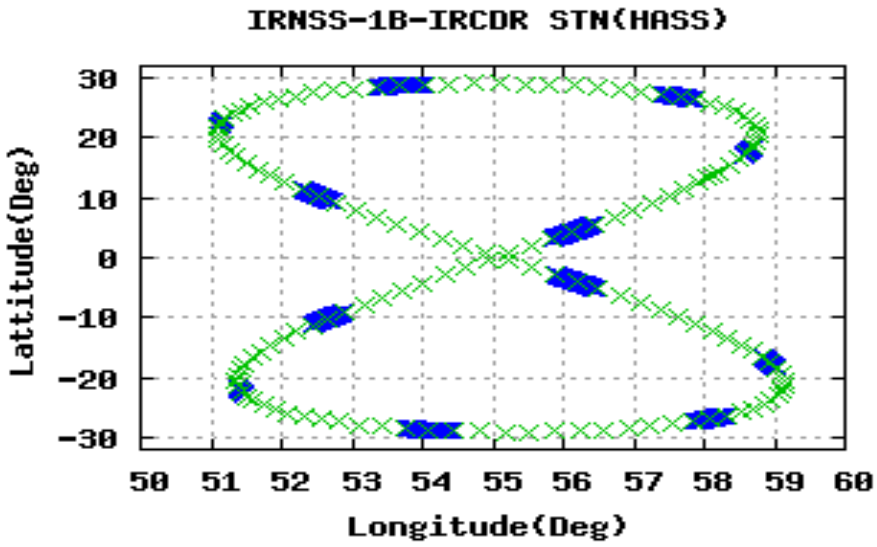
- **Measurements System:**
  - **One-way Range measurement from IRIMS has Receiver /Satellite clock and other errors**
  - **Two-way Range measurement from IRCDR , which is independent of clock errors**

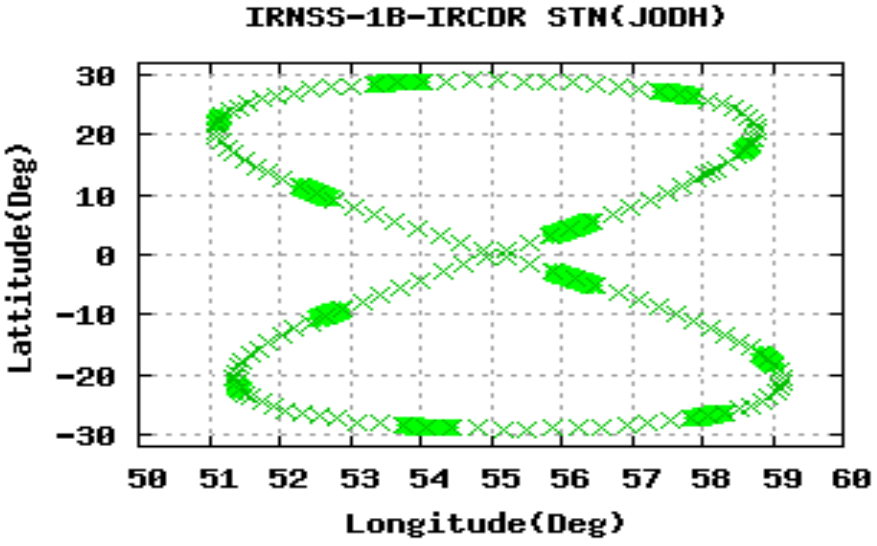
NavIC Two-Way Data And Processing

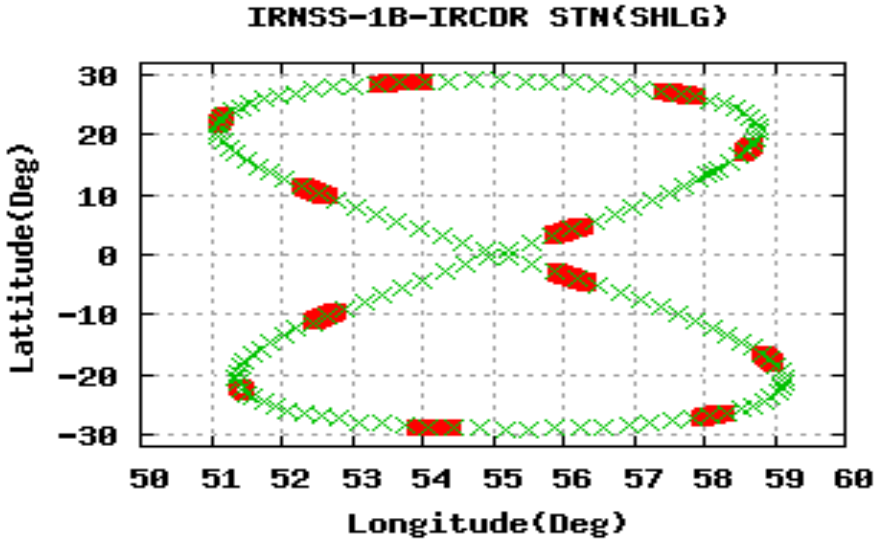
- **Two-way Data: Range and Ground Station calibration data from four Two-way Ranging stations (IRCDR) for each operational NavIC s/c is used.**
  - **For each NavIC S/c, data arc of 10-12min/2hr is available from each IRCDR station.**
  - **Ground station zero range calibration data of 5min/2hr is available**

NavIC Two-Way Data Availability



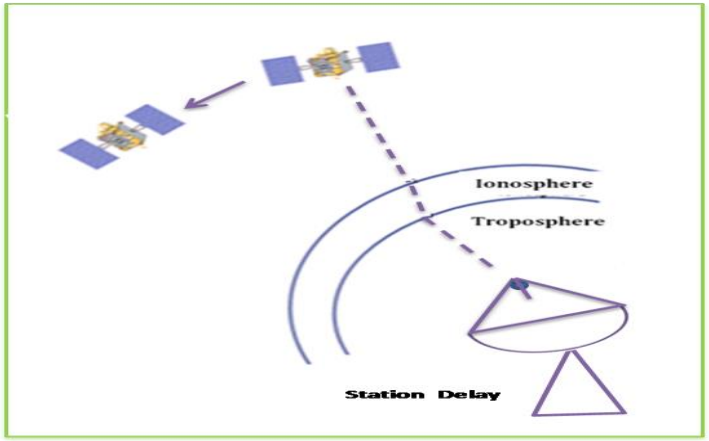




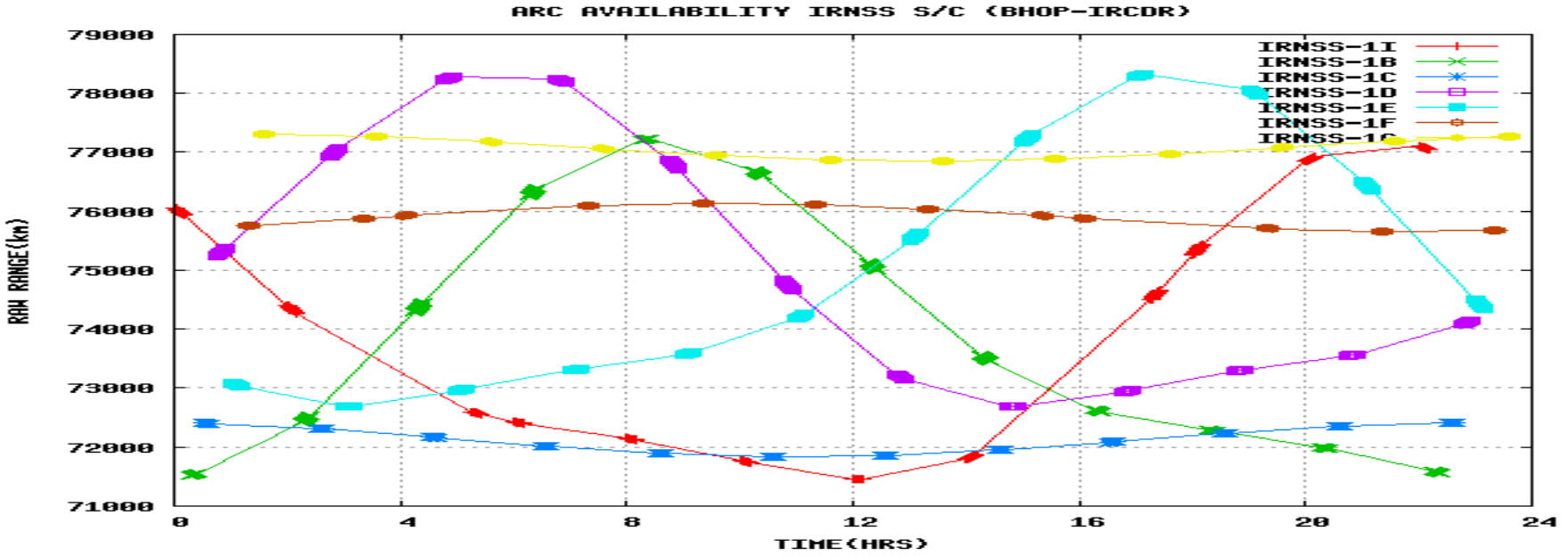


NavIC Two-Way Data Processing

- **Measurement Processing :**
  - ➢ **Removal of Outliers**
  - ➢ **IRCDR Station Delay Correction**
  - ➢ **Iono-delay Correction**
  - ➢ **Tropo-delay Correction**



- **Processed Range availability for OD**



NavIC Orbit Determination Using Two-Way Data

- **Dynamic Orbit Determination in NavIC Navigation Software**
- **Estimation:**
  - **Estimator : Least square**
  - **Mode : Batch processing**
  - **Span of data used : 3days**
  - **Number of parameters: X, Y, Z, Xdot, Ydot, Zdot + 9 empirical Accelerations**
- **Measurement models:**
  - **Satellite Antenna Phase Centre Correction**
  - **IRCDR Antenna Phase Centre Correction**
  - **Station Bias estimation: Arc-wise station bias estimation**

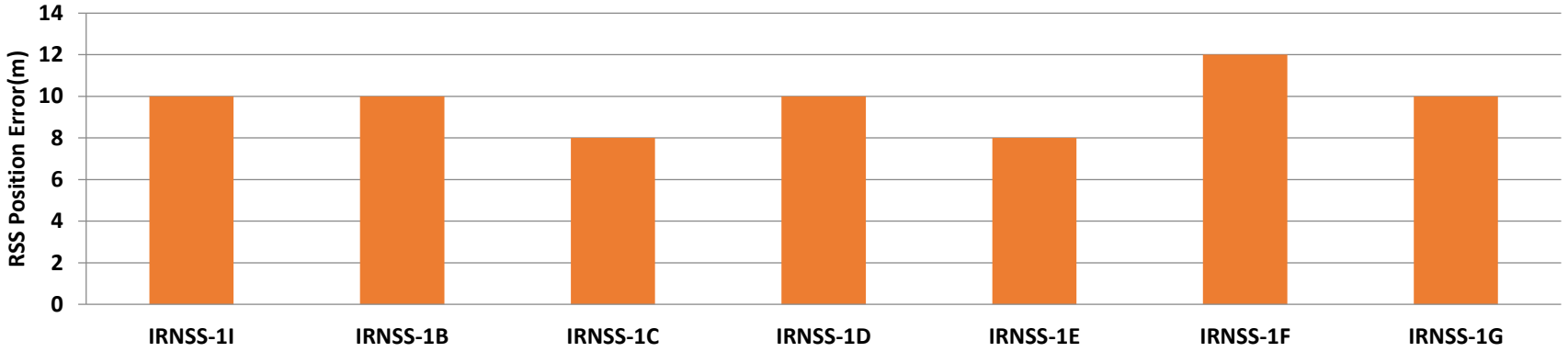
NavIC Orbit Determination Using Two-Way Data

- **Dynamic Orbit Model:**
  - Earth Gravity : EGM 2008(21X21)
  - N-body gravitation: JPL DE405(Sun, Moon and Other planets)
  - Solid Earth tide and Earth pole tide: IERS Conventions 2010
  - Ocean Tide and Ocean pole tide : IERS Conventions 2010
  - Relativistic effects : IERS Conventions 2010
  - Atmosphere drag : Not Considered
- **Reference Frame:**
  - Coordinate system : WGS 84
  - Precession/Nutation: IAU 2006/IAU2006A model
  - Earth rotation parameters : IERS final EOP products

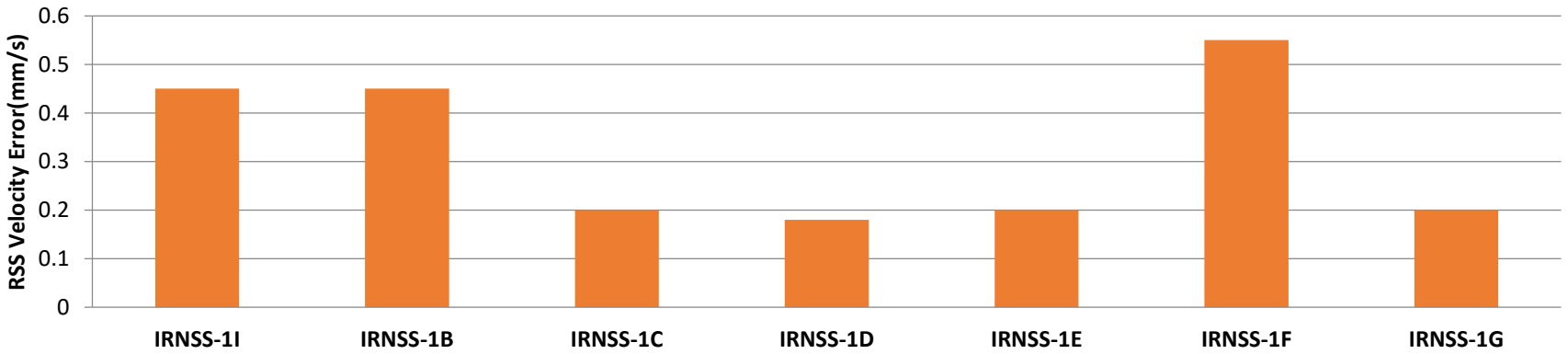
NavIC OD Using Two-Way Data – Results

ORBIT OVERLAP ERROR

RSS Pos Error(m) with σ =2m

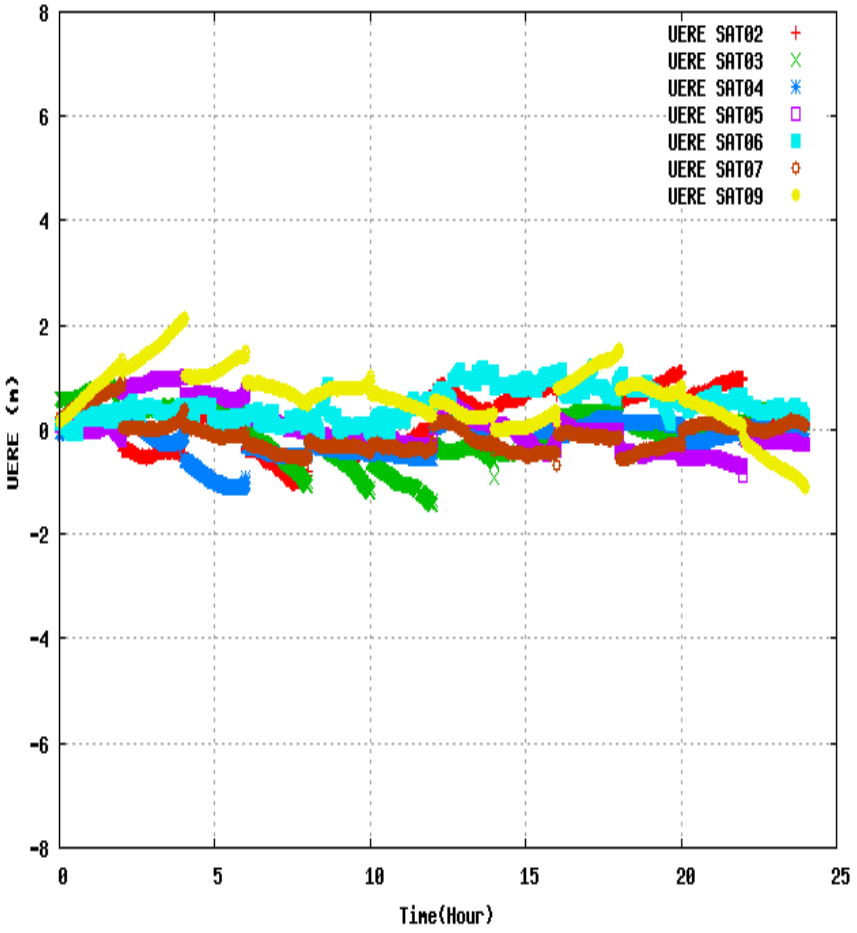


RSS Vel Error(mm/s) with σ =0.1mm/s

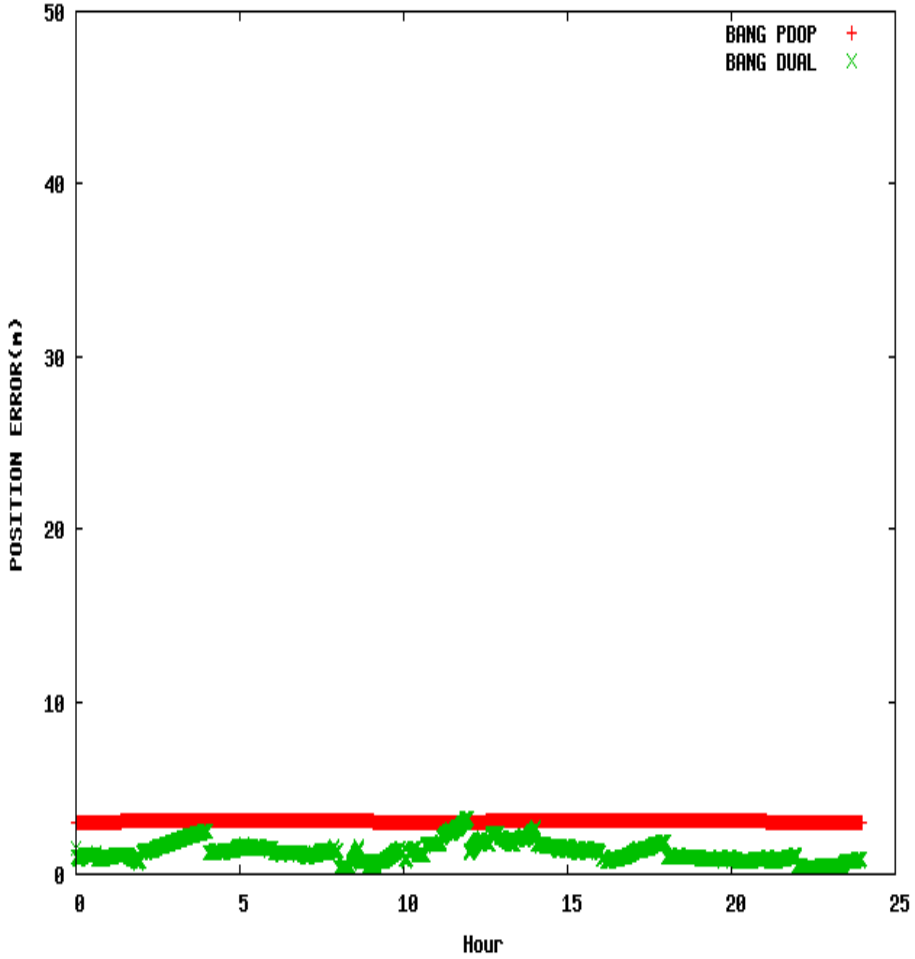


Typical Navigation Performance – Results

BLR-IRIMS: USER EQUIVALENT RANGE ERROR



BLR-IRIMS: POSITION ERROR



Extended Ephemeris of NavIC satellites

- To generate and disseminate extended ephemeris for NavIC satellites with longer usage period for SPS users of NavIC

Benefits

- To Provide Faster Time To First Fix(TTFF) through Extended (Longer Validity) Ephemeris under Following Adverse Conditions
  - Frequent Loss of Lock leads to loss of Broadcast Ephemerides(Poor signal Environments)
  - Cold Start of the receiver
- Faster TTFF under nominal Conditions with reasonable accuracy(20 to 100meters in position)

Navigation parameters

- NavIC satellites Broadcast Navigation Data and PRN codes to users to enable PVT fix.
- Navigation Data of SPS users Consists of
  - Ephemerides(Orbital State+ Clock Coefficients+URA+TGD..etc)
  - Almanac, Iono-Grid Parameters/ Klobaucher Coefficients, EOP(Earth-Orientation Parameters), Inter-Signal Corrections, and IRNWT offset etc.
- Ephemerides(Also called Primary Navigation Parameters) are broadcast at an interval of 48seconds and valid for short duration of 2hours
- Acquisition and Tracking takes about 3 seconds

Parameters	Message ID	Broadcast Interval
Iono-Grid Parameters	MT5	5mins
Klobaucher & EOP	MT11	10mins
Almanac	MT7	20mins
IRNWT offsets	MT26	20mins

Cont...

TTFF - Components

- Inputs for PVT
- Ephemerides
- Pseudo-Range

$T = T_{ack} + T_{tracking} + T_{eph} + T_{sol}$.

T_{ack} – Acquisition

T_{track} – Tracking

T_{eph} – Ephemerides Collection Time

T_{sol} - Solution computation duration

Teph is about 90% of Total TTFF

Nav. Data	Tinit sec	Tacq Sec	Tbsyn sec	Tvitb sec	Teph sec	Tpos sec	Total TTFF (T) (sec)	Tnav/ T
Broadcast	1	3	1	0.5	48	1	54.5	88%

Extended Ephemeris Generation

- Least square Fit
- Fit Interval – 8 Hours (3 sets per day)
- Two Types of Informations
  - Ephemeris
  - Events data
- Ephemeris Types

Ephemeris Type	Prediction Period	Update Interval	No. of sets	Size of data/satellite
1	24 Hours	Everyday	3	0.2KB
2	7 days	Once / week	21	1KB
3	21 days	Once /Week	84	4.2KB

Extended Ephemeris Generation

- Event Data
  - S/C Manoeuvre info.
  - Clock Jump info.
  - Planned S/C Maintenance, if any

Enhancement with Additional New Parameters

Extended Ephemeris includes all parameters of Subframes 1 and 2 with the following additional parameters to provided enhanced performance

Additional Parameters

S.NO	SUB-FRAME Data	Notation
1	Ephemerides Validity Period	E_VP
2	Time Of Differential Corrections	t_{od}
3	Diff. Cor. Validity Period	DC_VP
4	Issue of data Differential Correction	IODDC
5	Issue of data Differential Cor. and Ephemeris	IODDE
6	Alpha correction to ephemeris parameters	$\Delta\alpha$
7	Beta correction to ephemeris parameters	$\Delta\beta$
8	Gamma correction to ephemeris parameters	$\Delta\gamma$
9	Angle of inclination correction	Δi
10	Events Data	ED_MSG

Expected Performance of Extended Ephemeris-TTFF

BEST CASE

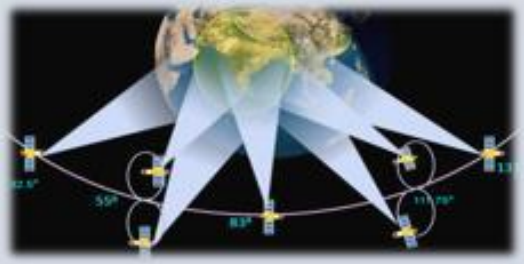
Nav. Data	Tinit sec	Tacq Sec	Tbsyn sec	Tvitb sec	Teph sec	Tpos sec	Total TTFF (sec)
Broadcast	1	3	1	0.5	48	1	54.5
Ext. Eph.	1	3	1	0.5	0	1	6.5

WORST CASE

Nav. Data	Tinit sec	Tacq Sec	Tbsyn sec	Tvitb sec	Teph sec	Tpos sec	Total TTFF (sec)
Broadcast	1	3	1	0.5	60	1	66.5
Ext. Eph.	1	3	1	0.5	0	1	6.5

Conclusion

- Two-way range measurements accuracy ~0.3m (2σ)
- Achieved orbit accuracy is ~ 8m-12m (3σ RSS) over a day based on the overlap analysis
- Utilization:
  - Estimated orbital parameters from Two-way measurements are used to generate the NavIC navigation parameters
- Additional data with long base line is expected to improve the orbit accuracy
- Using Extended ephemeris 90% reduction in TTFF w.r.t broadcast under Initial Position Fix
- Lot of new applications possible
  - Mobile Phones
  - Activity trackers and eHealth
  - Wearables Technologies



Thank You