Quicklook: A Testbed for an Automated Orbit Determination System Using the Cassini Spacecraft

Jeroen Geeraert and Sumita Nandi

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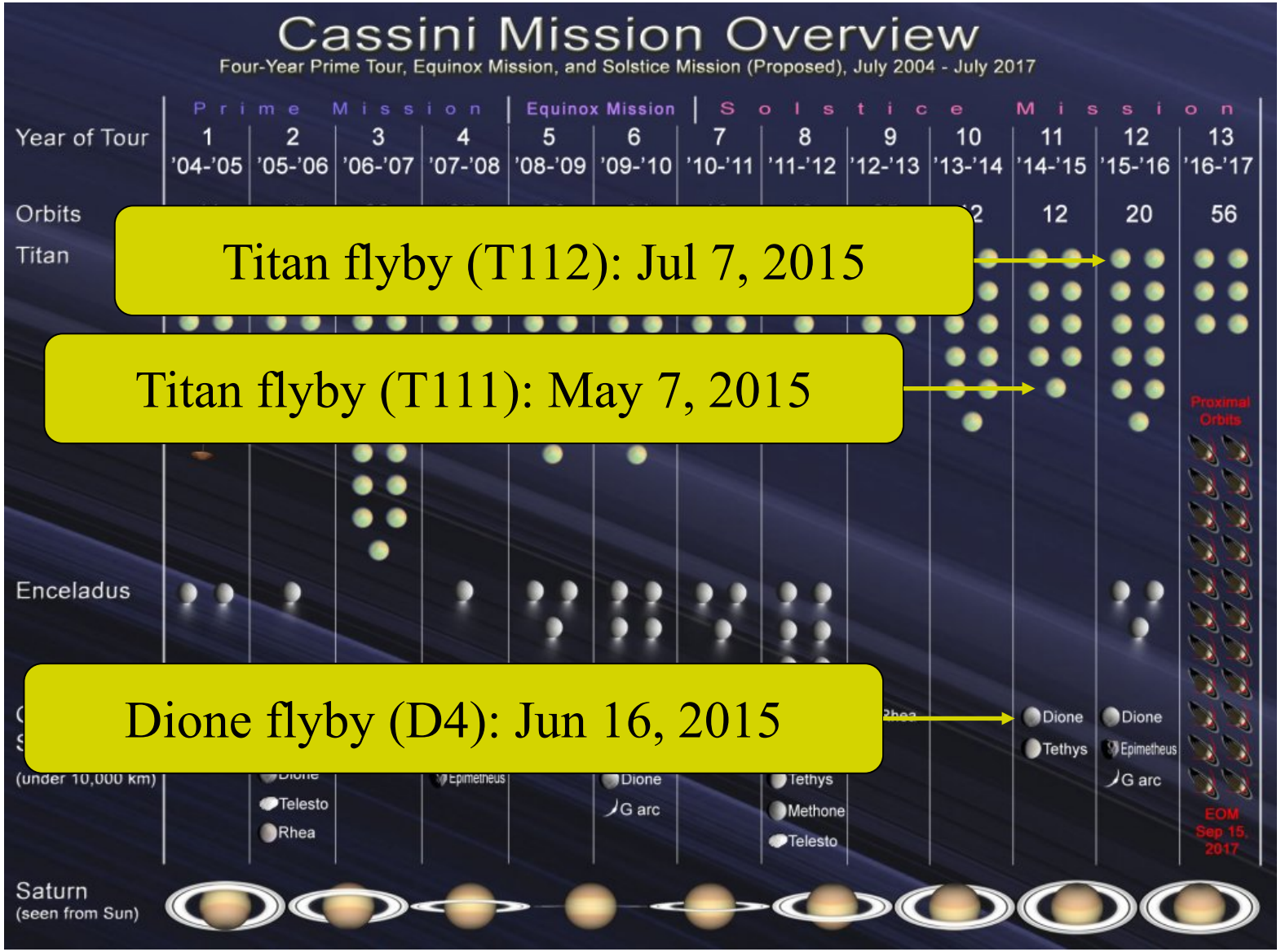
Overview

- Cassini Mission Overview
- Motivation for Automated Orbit Determination (OD)
- How and Quicklook (QL) High-Level Structure
- Known Differences
- Example of Quicklook Deliverables
- Verification of Results

Mission Overview

- Cassini-Huygens launched on October 15, 1997
- Saturn Orbit Insertion (SOI) on July 1, 2004
- Prime Mission: Jul 2004 – Jul 2008 (4 years)
- Equinox Mission: Jul 2008 – Sep 2010 (2 years)
- Solstice Mission: Sep 2010 – Sep 2017 (7 years)
  - 56 targeted Titan flybys
  - 12 targeted Enceladus flybys
  - 5 targeted Dione and Rhea flybys
  - 214 planned maneuvers

Mission Overview



Titan flyby (T112): Jul 7, 2015

Titan flyby (T111): May 7, 2015

Dione flyby (D4): Jun 16, 2015

[1]

Mission Overview

Most Complex Gravity-Assist Trajectory ever Flown

[2]

Motivation for Automated OD

- Rich dynamical environment provides a useful testbed for an automated OD system
- Short-term goals
  - Increase integrity of the OD solution evolution
  - Early indication of potential upcoming problems
  - Provide redundancy
- Long-term goals
  - Develop proof-of-concept for a robust automated system
    - Unpredicted dynamic events
    - Data anomalies

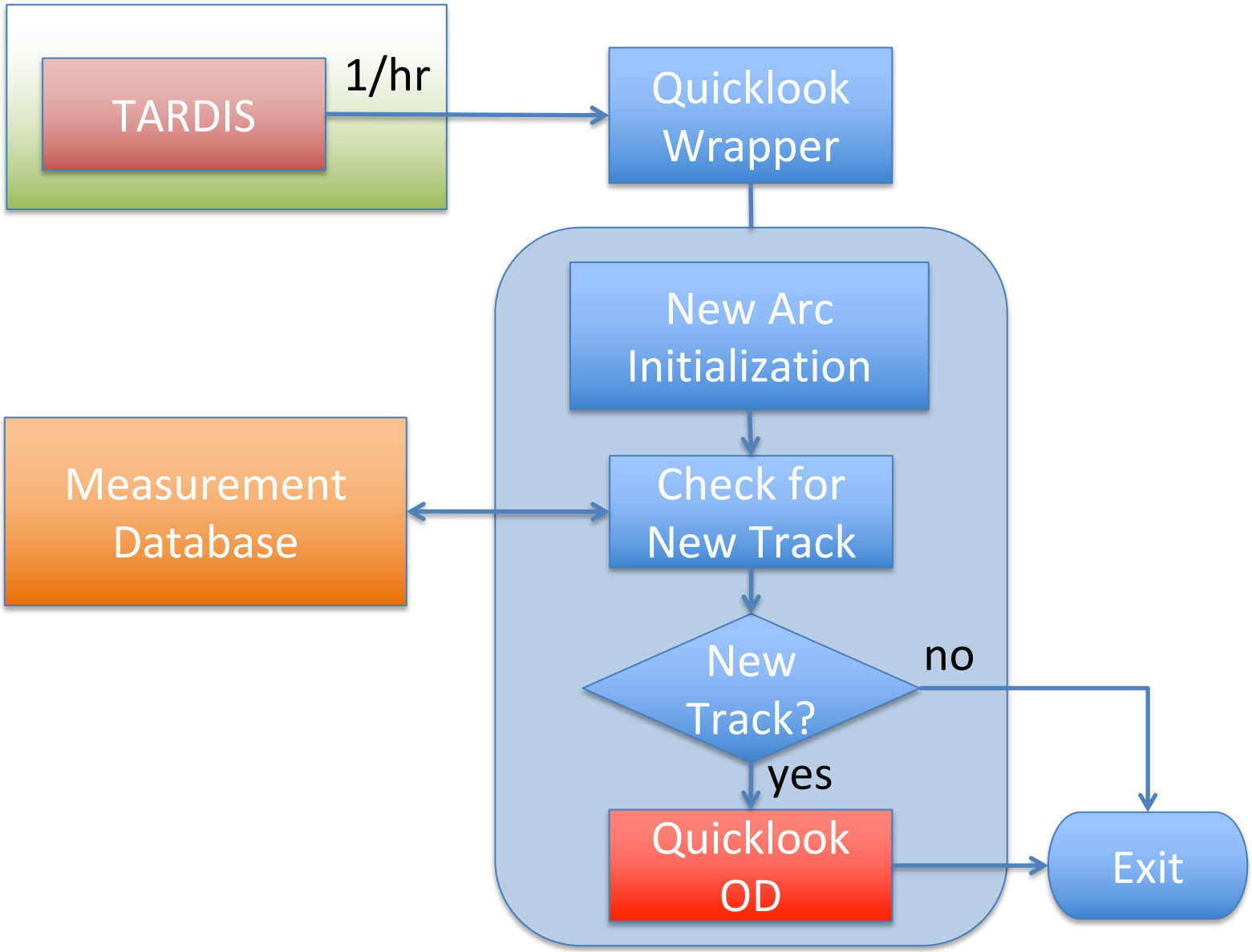
Integrity of OD Solution Evolution

- Since 2nd extended mission, staffing levels are reduced
- Currently Cassini demands three rotations of two analysts for OD
- Analyst OD solution usually computed after multiple DSN tracks
- Quicklook can provide OD solutions more frequently, after every DSN track

How

- Quicklook acts like a virtual analyst using the same OD tools and procedures as the analysts
- Scripted using Monte Python
- Automated using the Traceable Automation with Remote Display and Interruptible Scheduler (TARDIS) system
- Results are e-mailed to the OD team
- Results available in similar directory structure as analyst working OD directory

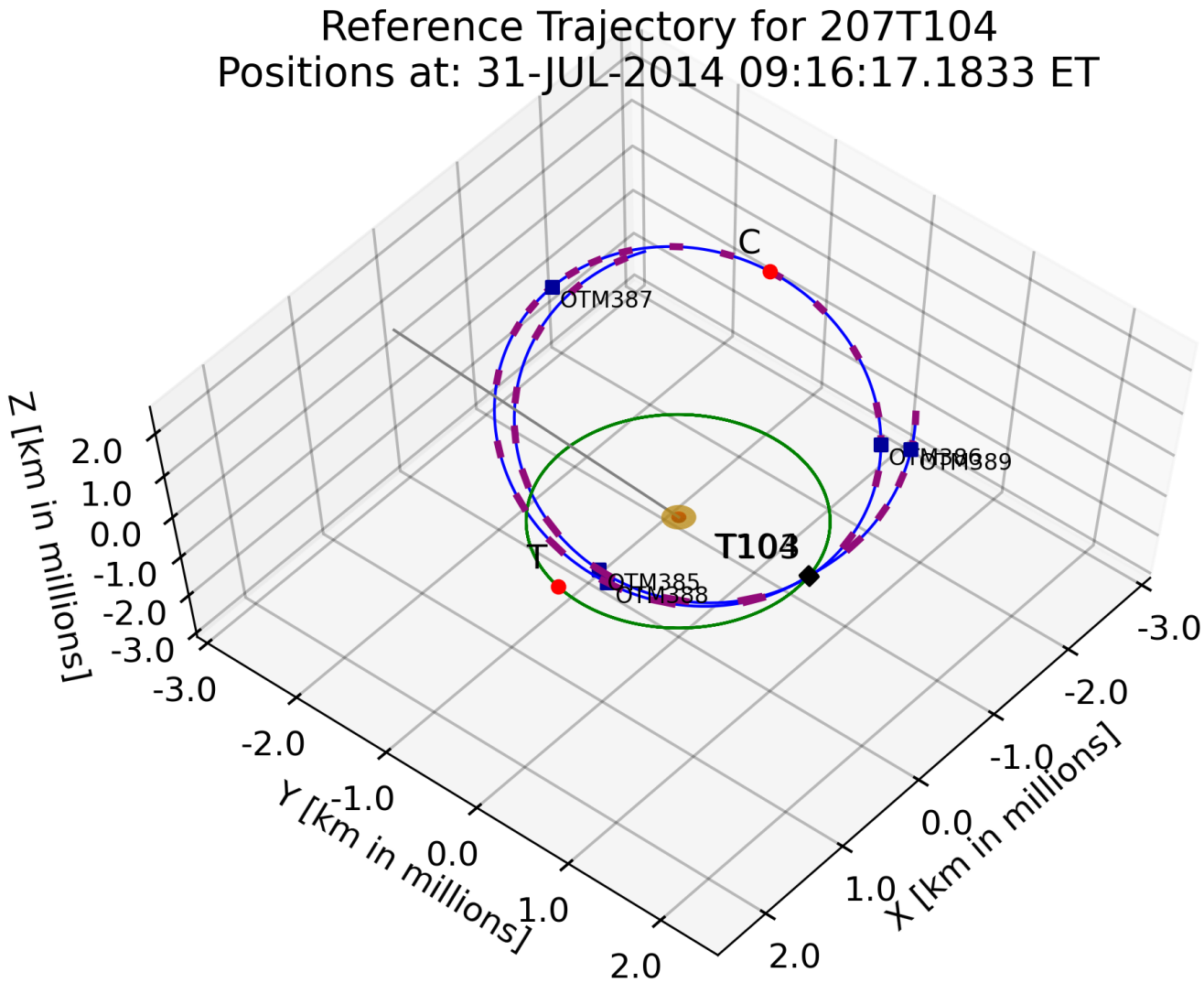
Quicklook Structure Overview



Known Differences between QL and Ops

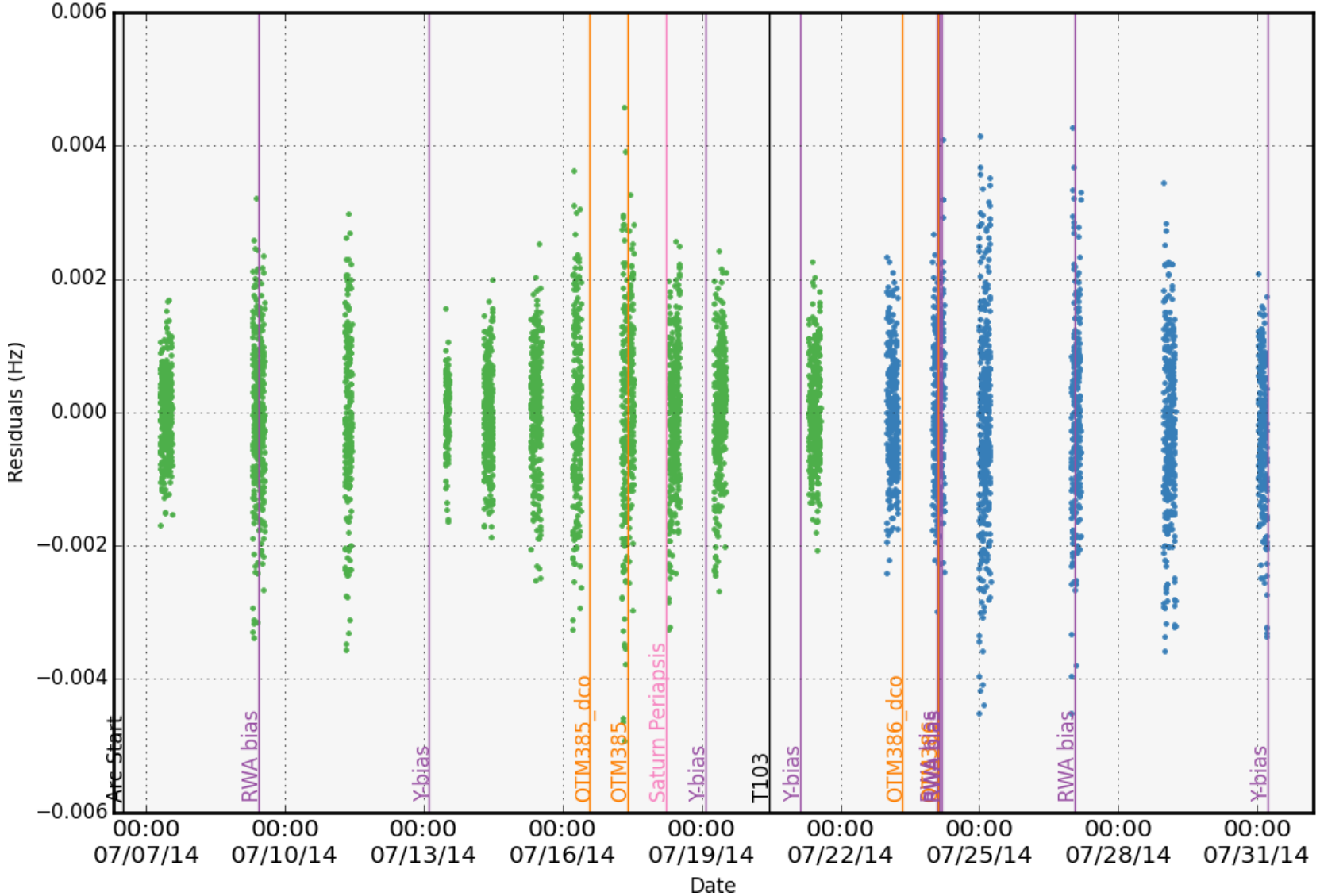
- Preset weights per data type (for new tracks)
- Delay in use of the Orbit Trim Maneuver telemetry file
- Does not account for modeling changes between Quicklook delivery and analyst Ops delivery e.g. change in small maneuver model (time or Δv)

Example: Visualization

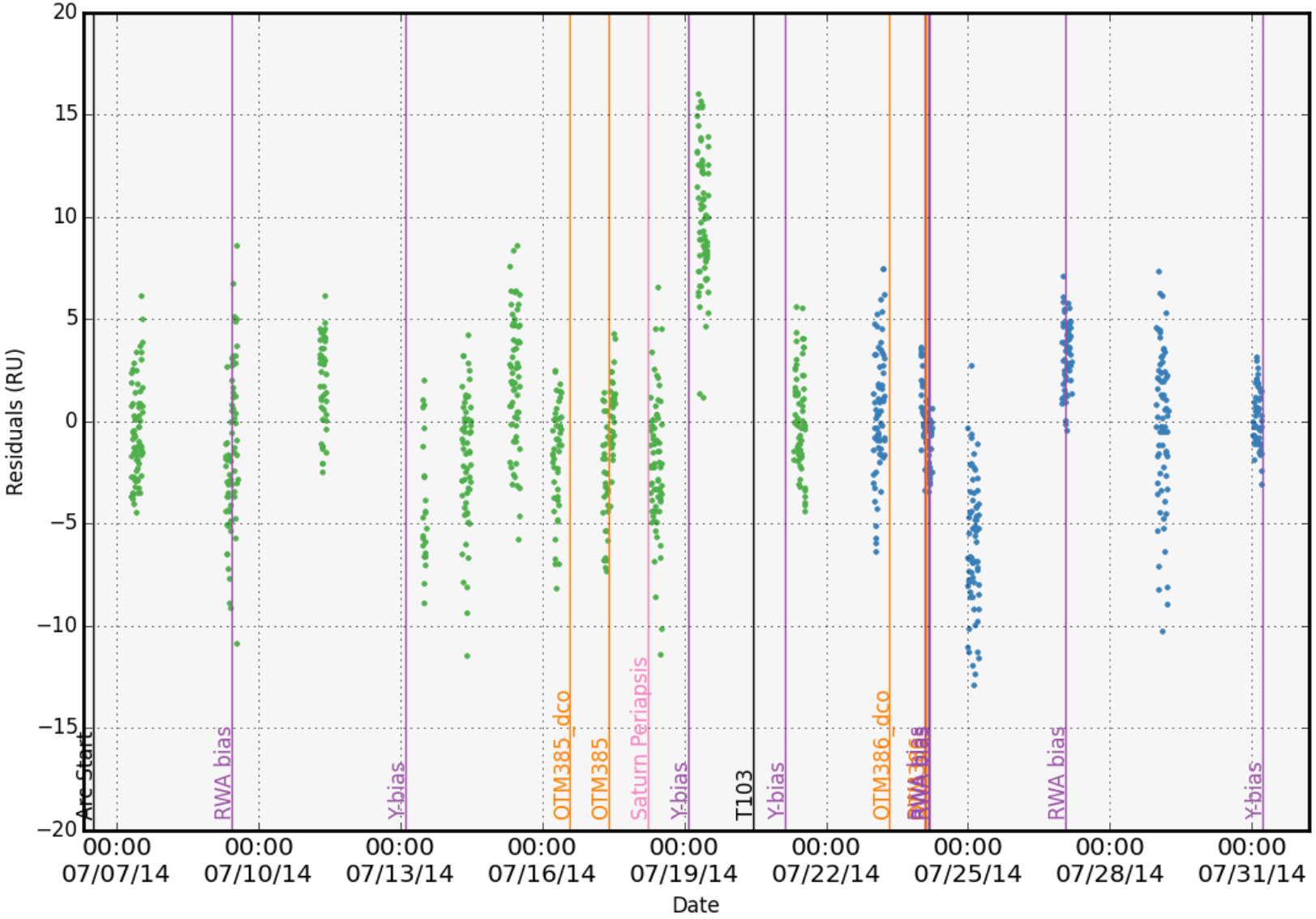


Example: Doppler Residuals

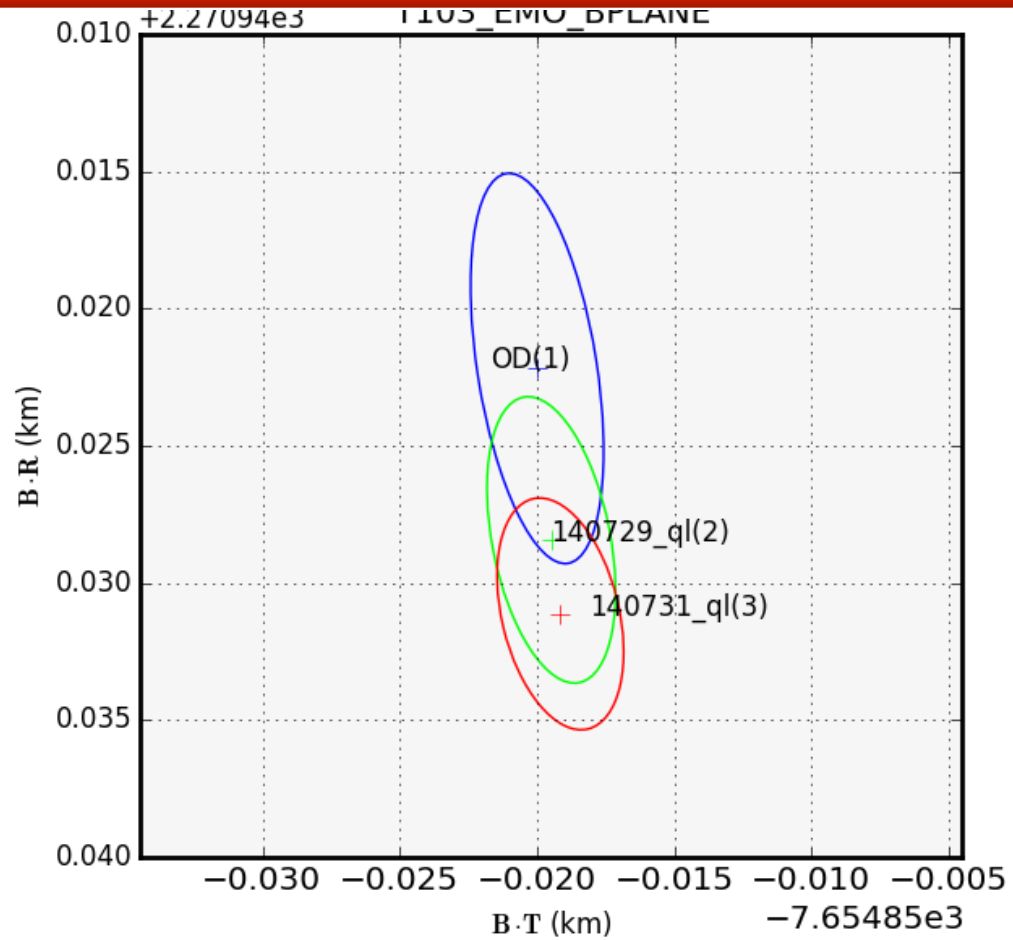
Cassini Navigation

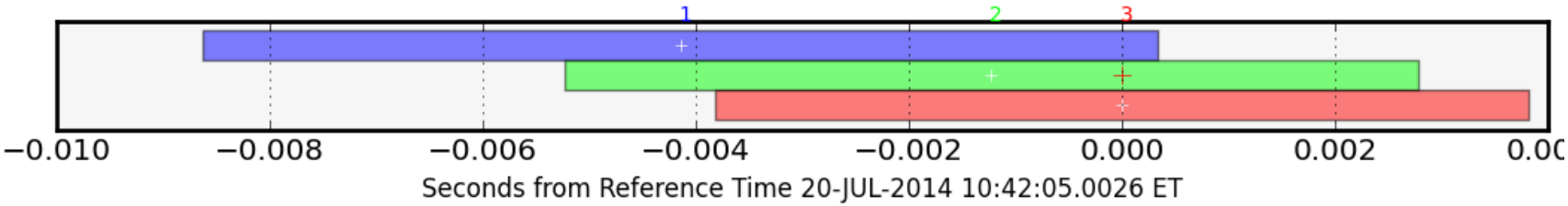


Example: Range Residuals

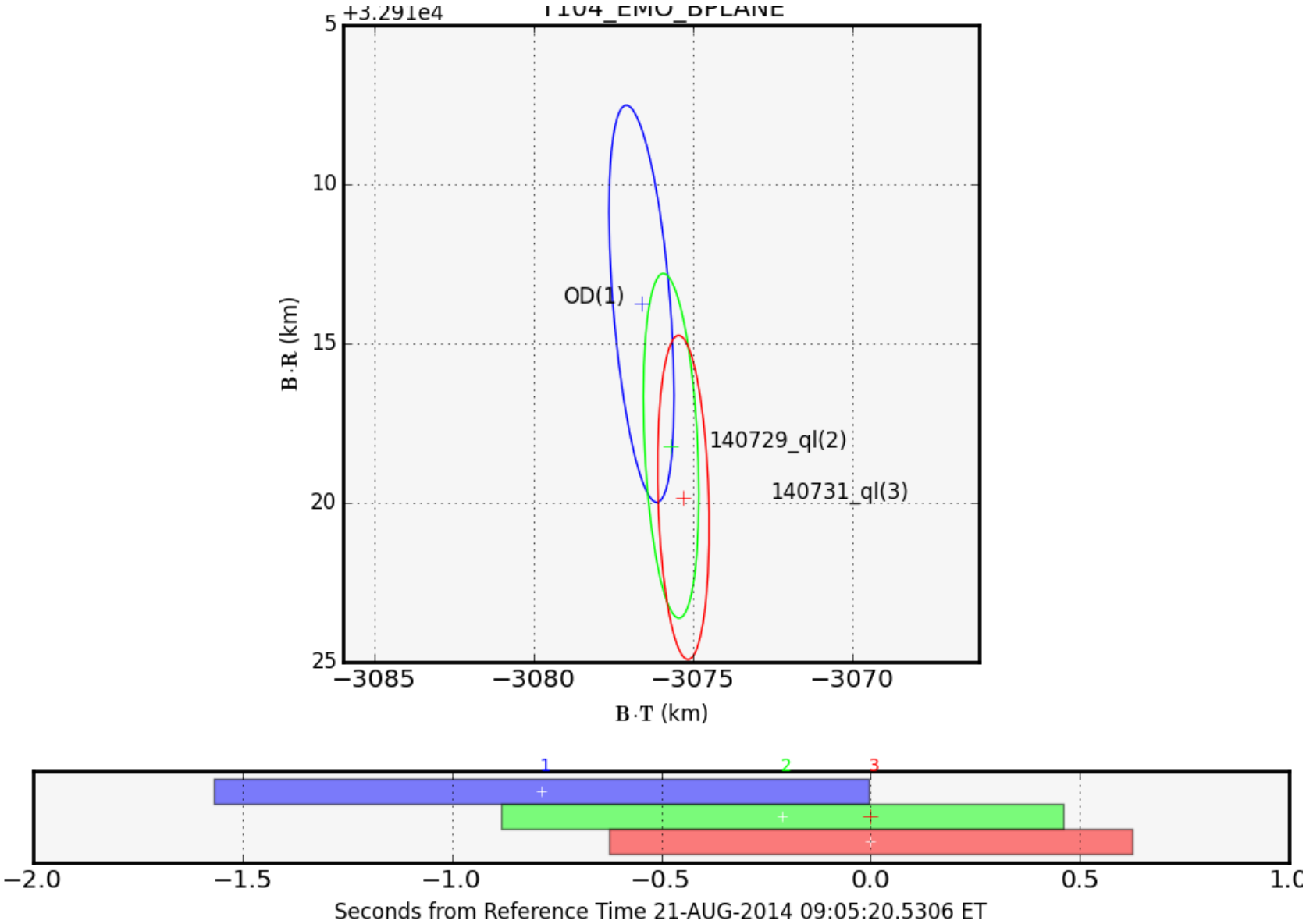


Example: T-103 B-Plane





Example: T-104 B-Plane



Example: Approach Maneuver Design

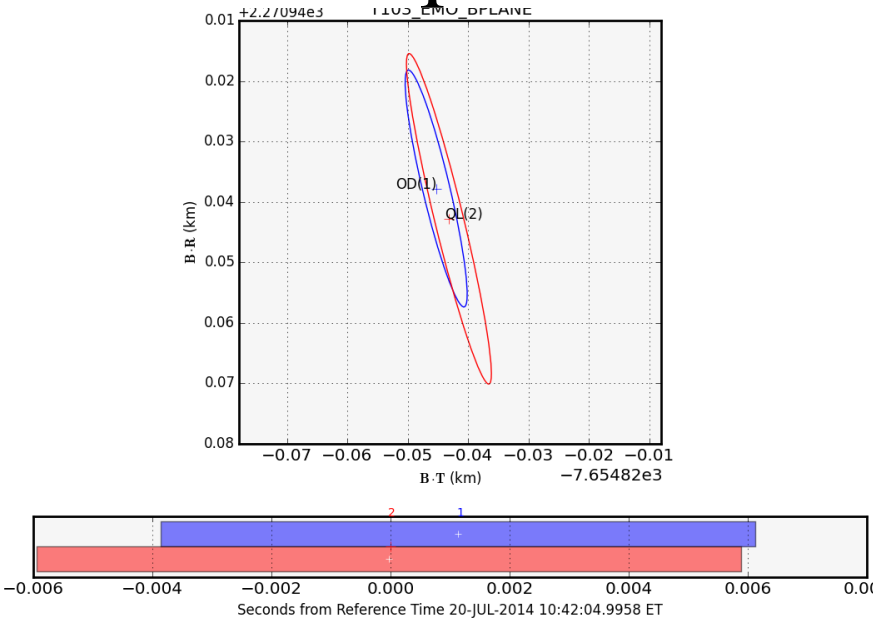
- Statistical approach maneuver usually occurs 3 days before flyby
- If Cassini is past the apocrone maneuver but before the approach maneuver then Quicklook estimates size of approach maneuver

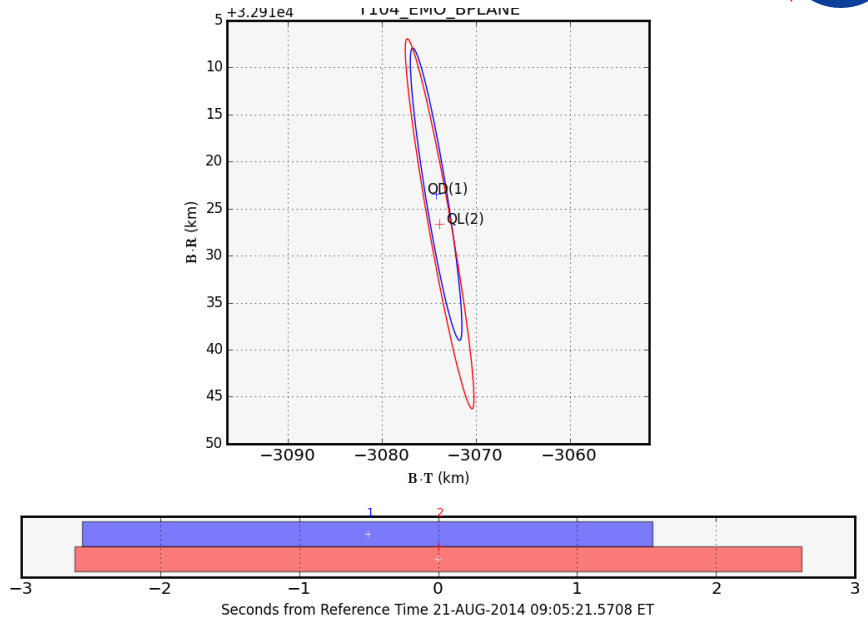
Quicklook Maneuver	**Delivered Maneuver**
ΔV: 32.2 mm/s	ΔV: 32.2 mm/s
RA: 91.212º	RA: 91.319º
Dec: -38.324º	Dec: -38.164º

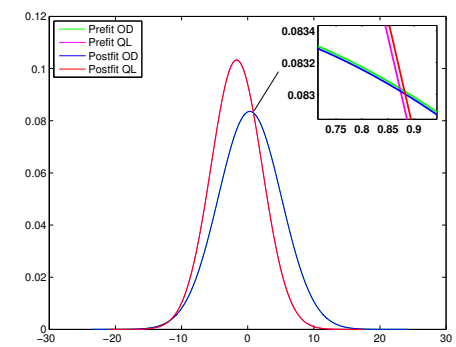
Output Verification

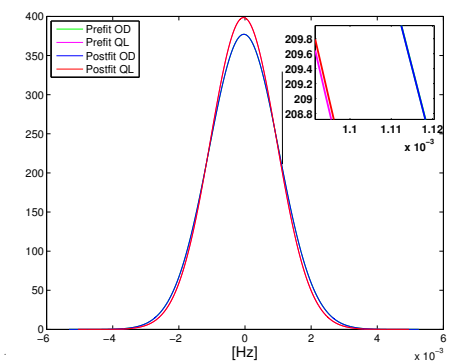
- Compare Quicklook and Ops for each delivered Ops solution
  - Quicklook has solution after each track
  - Ops usually has solution after several tracks
- Metrics
  - B-plane ellipse
    - Size
    - Orientation
    - Location
  - Residual Statistics
    - Pre/postfit

Output Verification: 07/21/2014



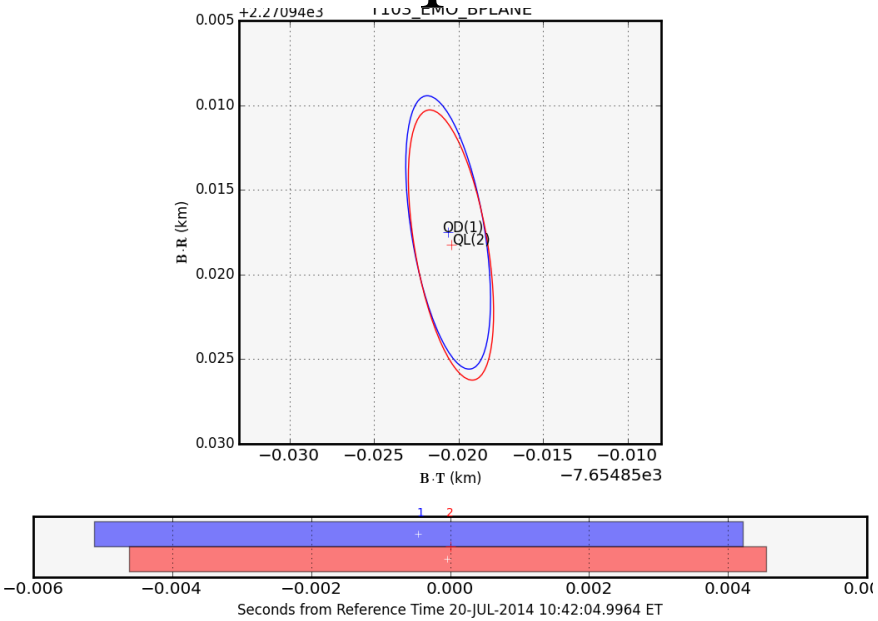


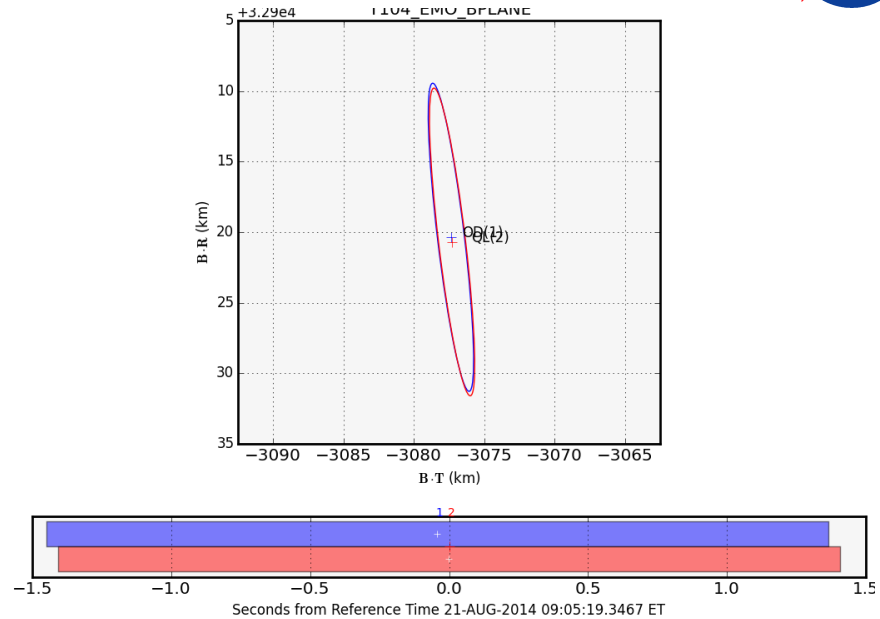


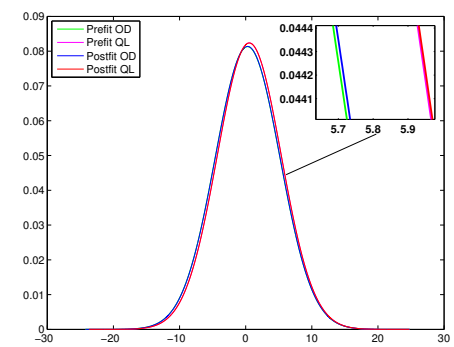


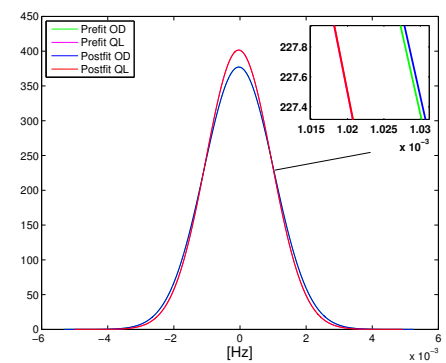
	Analyst	Quicklook	Diff
Range Prefit STDEV	4.7736e+00	3.8644e+00	9.0926e-01
Range Postfit STDEV	4.7744e+00	3.8607e+00	9.1366e-01
Doppler Prefit STDEV	1.0578e-03	1.0011e-03	5.6734e-05
Doppler Postfit STDEV	1.0578e-03	1.0011e-03	5.6654e-05

Output Verification: 07/23/2014



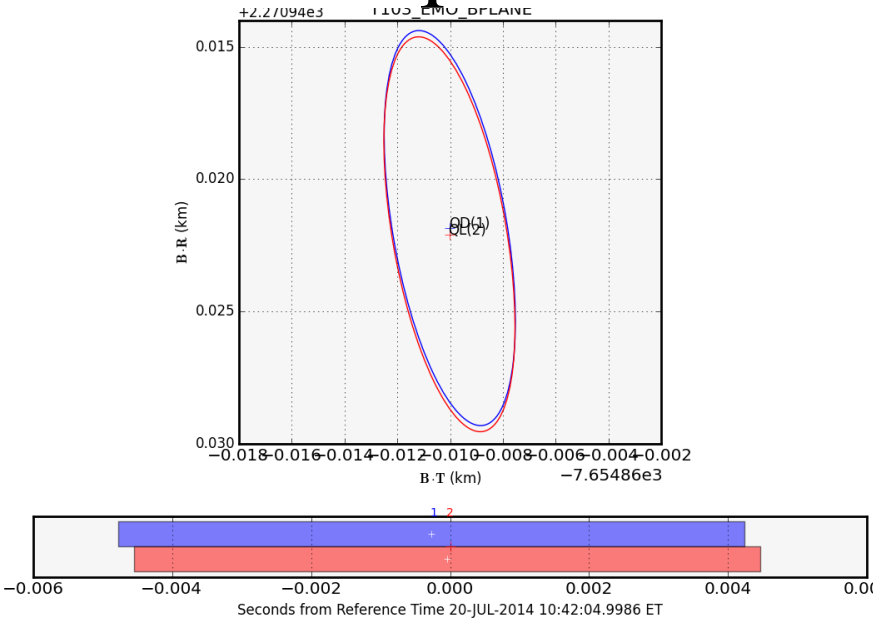


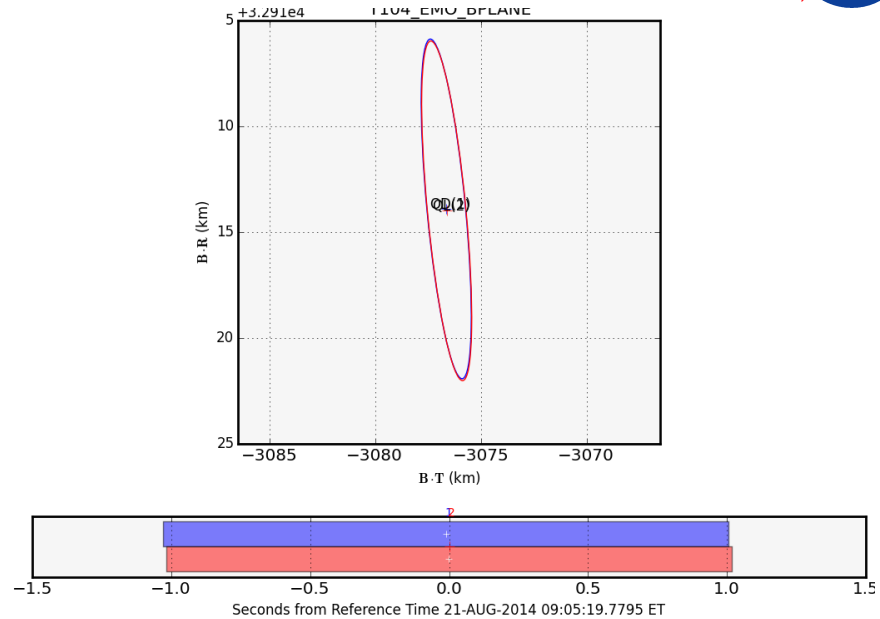


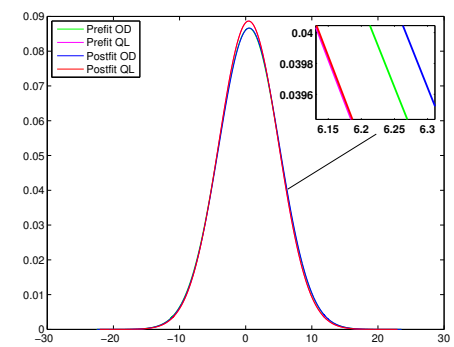


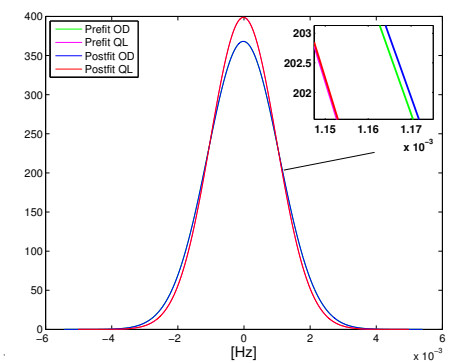
	Analyst	Quicklook	Diff
Range Prefit STDEV	4.9067e+00	4.8425e+00	6.4170e-02
Range Postfit STDEV	4.9027e+00	4.8441e+00	5.8590e-02
Doppler Prefit STDEV	1.0576e-03	9.9342e-04	6.4197e-05
Doppler Postfit STDEV	1.0577e-03	9.9346e-04	6.4205e-05

Output Verification: 07/24/2014









	Analyst	Quicklook	Diff
Range Prefit STDEV	4.6070e+00	4.4999e+00	1.0716e-01
Range Postfit STDEV	4.6040e+00	4.4998e+00	1.0422e-01
Doppler Prefit STDEV	1.0838e-03	1.0004e-03	8.3486e-05
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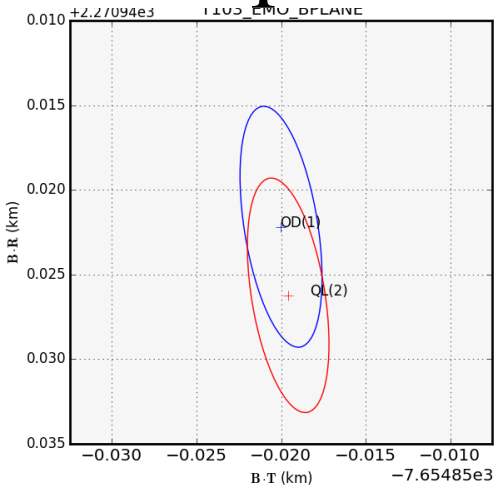
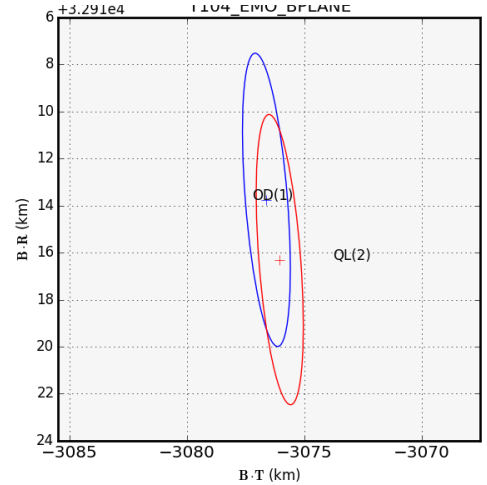
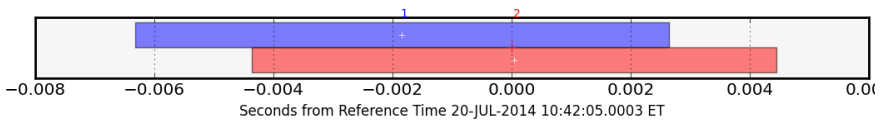
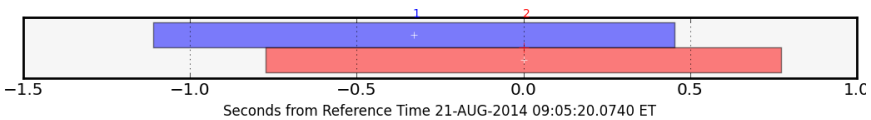
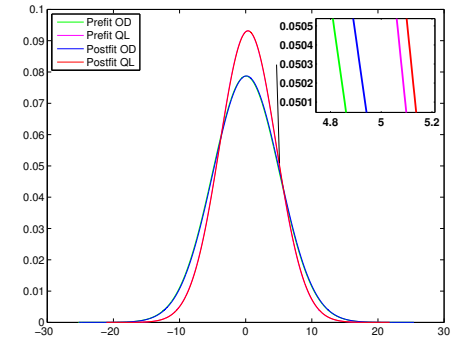
Output Verification: 07/27/2014

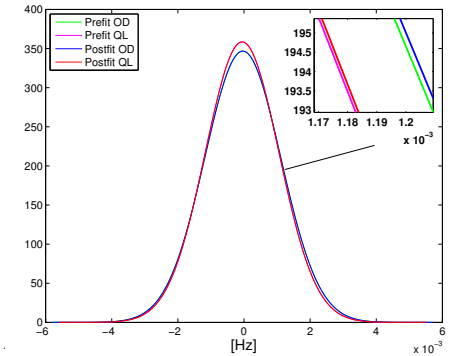






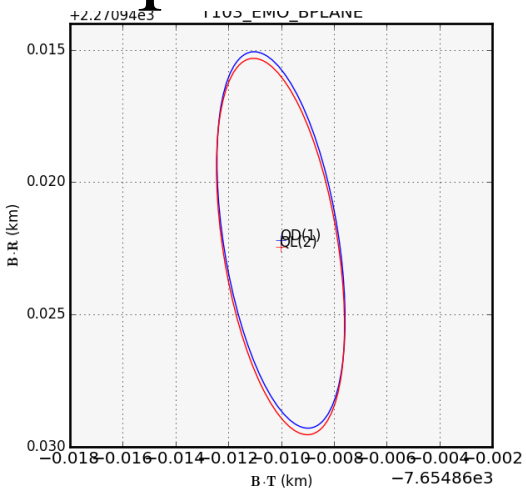


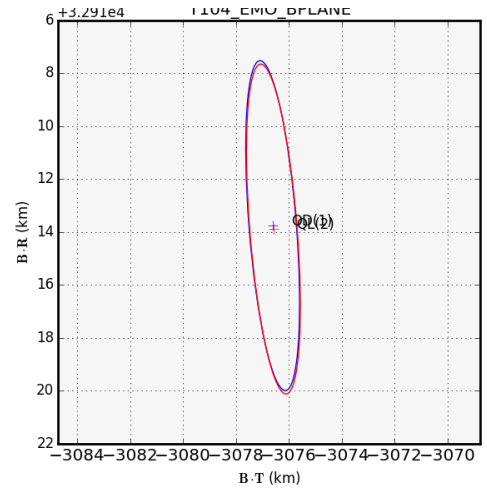


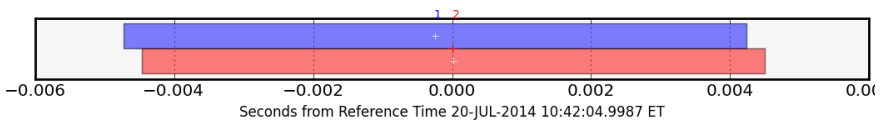


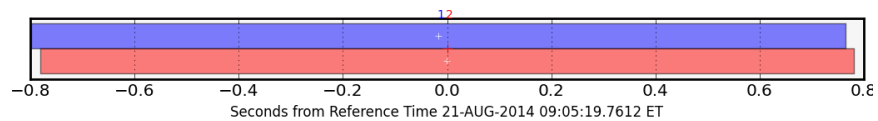
	Analyst	Quicklook	Diff
Range Prefit STDEV	5.0709e+00	4.2823e+00	7.8854e-01
Range Postfit STDEV	5.0666e+00	4.2831e+00	7.8351e-01
Doppler Prefit STDEV	1.1507e-03	1.1128e-03	3.7728e-05
Doppler Postfit STDEV	1.1507e-03	1.1129e-03	3.7780e-05

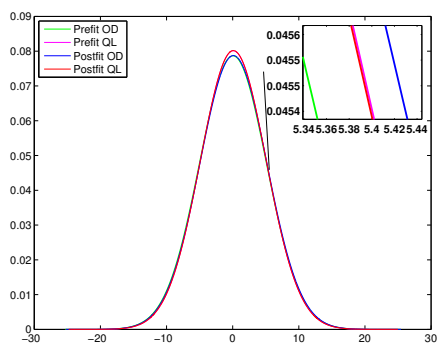
Output Verification: 07/27/2014 Redo

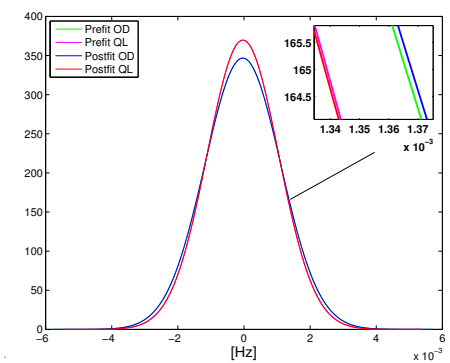












	Analyst	Quicklook	Diff
Range Prefit STDEV	5.0709e+00	4.9780e+00	9.2896e-02
Range Postfit STDEV	5.0666e+00	4.9761e+00	9.0529e-02
Doppler Prefit STDEV	1.1507e-03	1.0792e-03	7.1522e-05
Doppler Postfit STDEV	1.1507e-03	1.0792e-03	7.1548e-05

Summary

- Demonstrated a preliminary automated OD system for navigation in highly dynamic environment
- Verified results
- Stepping stone for more robust implementation for the dynamic navigation problem of future missions

Acknowledgements

- Mentor: Sumita Nandi
- Supervisor: Shyam Bhaskaran
- Julie Bellerose
- Dylan Boone
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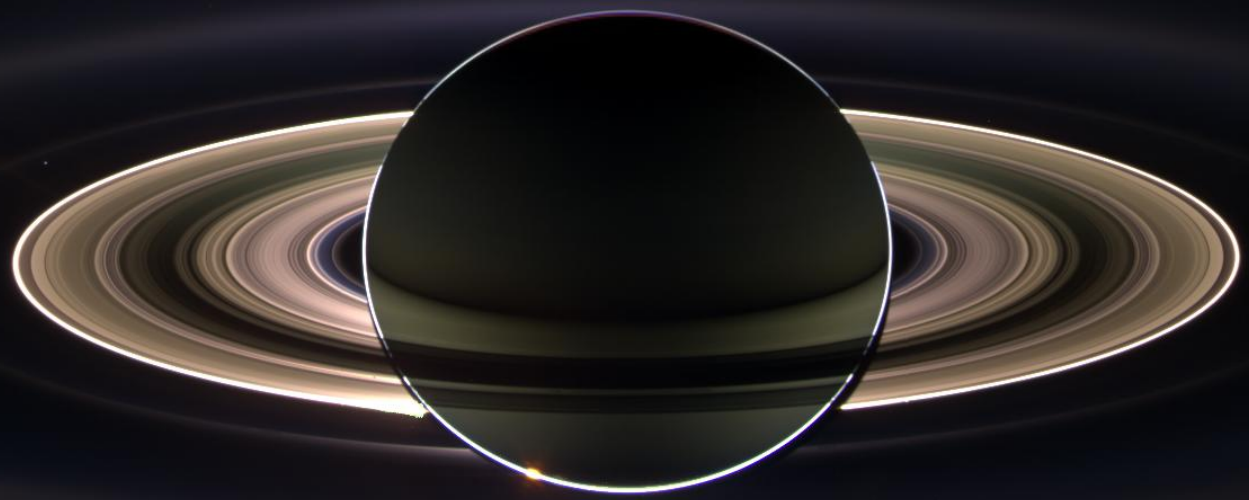
- Duane Roth
- Ian Roundhill
- Jonathon Smith
- Rick Kelly
- Robert Beswick

[1] Image courtesy of Dave Seal.
[2] Ballard, C.G., ed. *Cassini Solstice Navigation Plan*. N.P.: Jet Propulsion Laboratory, California Institute of Technology, 2010.
[3] Image courtesy of JPL.



QUESTIONS?