# NavCom Global StarFire™ Service

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# Agenda

- Introduction
- StarFire system description
- Legacy StarFire service
- StarFire GNSS performance and applications
- StarFire /RTK integration - RTK-Extend
- Summary

# What is StarFire?

- Worldwide Satellite Based Augmentation System (SBAS)
- Broadcasts GPS/GNSS satellite clock and orbit corrections
- Utilizes L-band satellites in geosynchronous orbits to provide global coverage

**5 Centimeters* Globally Without a Base Station**


*: actual performance may vary and depends upon propagation of electromagnetic signals (e.g., ionospheric propagation), satellite performance, solar flare activity and other environmental factors



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# StarFire System

User – Receivers and System



Ground Tracking - Global Network

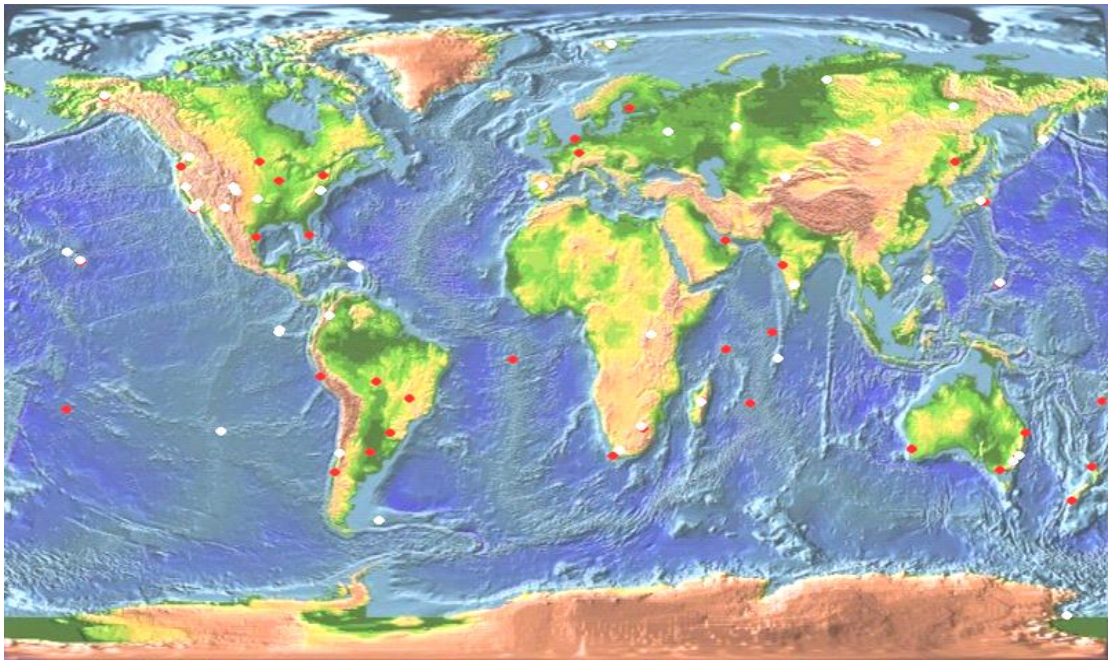

Space – Signal Distribution

Control - Processing Center

**GPS→GPS+GLONASS, GNSS**

# Global Tracking GNSS Network

- 40+ Ashtech GPS receivers licensed from JPL in white
- Added 100+ SF-3050 GNSS receivers in 40+ John Deere sites in red
- Upgraded network tracks all GNSS satellites continuously
- Processing centers receive GNSS measurements from each reference receiver continually



# StarFire Control Processing Centers

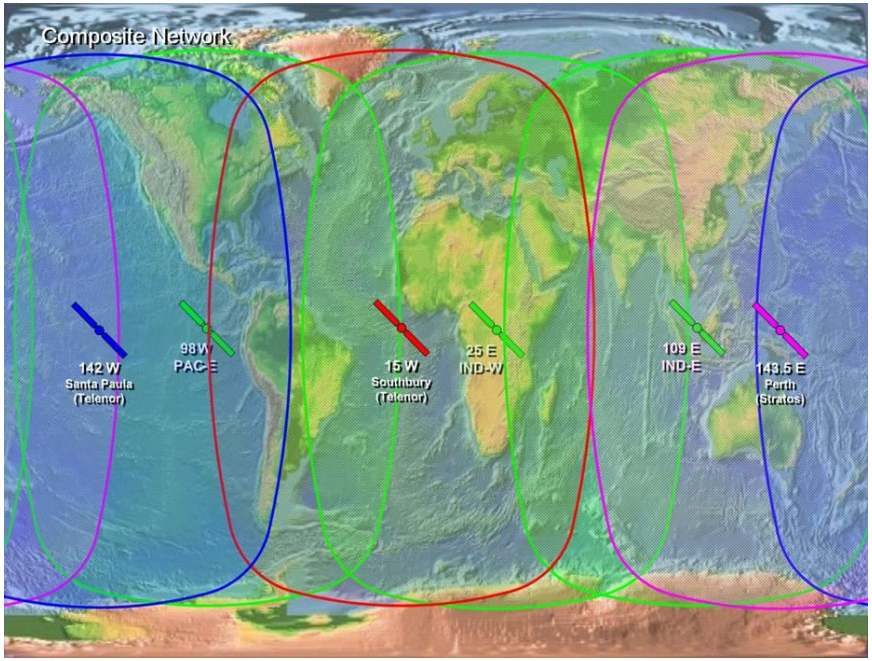
- **Two Processing Centers**
  - El Segundo, California
  - Moline, Illinois

- **Two Independent StarFire Software Solutions**
  - Real-Time RTG licensed  from JPL : GPS only
  - iCORE developed by NavCom Technology : GPS+GLONASS

# StarFire Uplink and Space Segment

- StarFire channels on global beams of 6 different L-band communication satellites
- Legacy GPS receivers use legacy StarFire signals
- StarFire GNSS receivers can use both legacy and StarFire GNSS signals from two of six sources
  - Americas –Laurentides, Canada
  - Americas – Santa Paula, CA
  - Europe – Burum, Netherlands
  - Europe – Southbury, CT
  - Asia – Perth, Australia
  - Asia - Auckland, New Zealand

Redundant Uplink Sites, Satellites and Corrections



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# Integrated StarFire Receivers



## StarFire 3000

- Multi-frequency StarFire/RTK GNSS receiver
- MEMs inertial attitude determination

## StarFire SF-3050 Series

- Military, Offshore, Machine Control markets
- Full GNSS capability
- CORS receiver

## StarFire SF-3040 Series

- Pole-Mount StarFire/RTK GNSS survey receiver

## Legacy StarFire receivers

- StarFire iTC
- StarFire SF-2050 and SF-2040



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# Redundancy Everywhere

- Redundancy in reference network: JPL + John Deere
- Redundancy in StarFire reference receivers
- Redundancy in processing centers
- Redundancy in StarFire clock and orbit solutions
- Redundancy in uplink sites
- Redundancy in satellites in view
- Redundancy in  StarFire correction streams
- Redundancy in StarFire receiver navigation solutions

# StarFire System Reliability

**Reliability achieved by ensuring no single point of failure and thorough monitoring and redundancy**

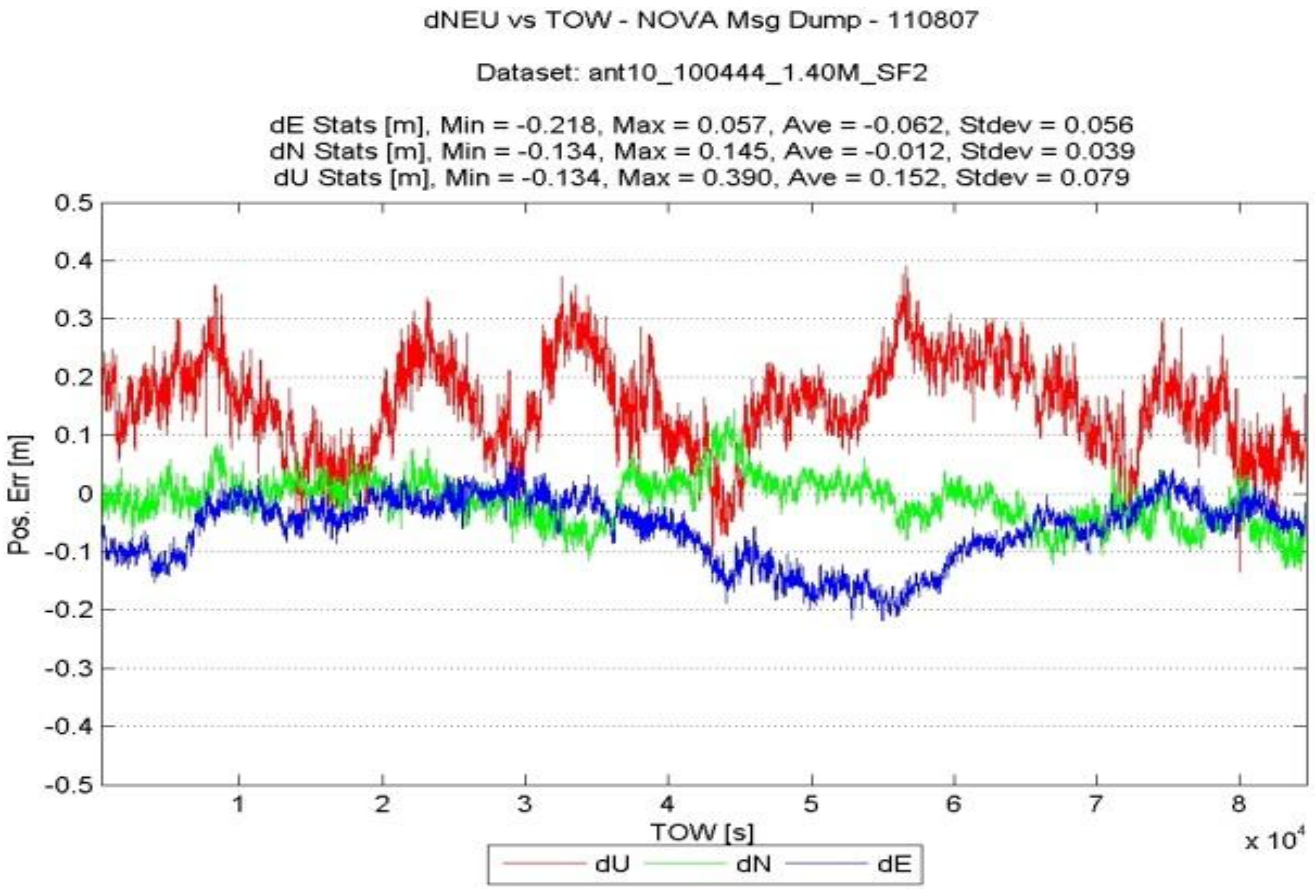
- Redundancy throughout entire StarFire system
- Extensive real-time monitoring
  - Worldwide monitoring stations
  - Real-time positioning results
  - Automated system metrics & alarms
- 99.999% availability of the StarFire correction service
  - Under 6 minutes of outage annually
  - StarFire GNSS system has provided continuous service without user downtime since December 2010

# StarFire GPS (Legacy StarFire)

- JPL network of 40+ Ashtech GPS receivers
- Real-Time RTG processing software licensed from JPL
- Single GNSS (GPS) System
- Sub-decimeter level position performance globally

# Legacy StarFire GPS Only

## Torrance Rooftop, Static, Open sky



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# StarFire GNSS Service

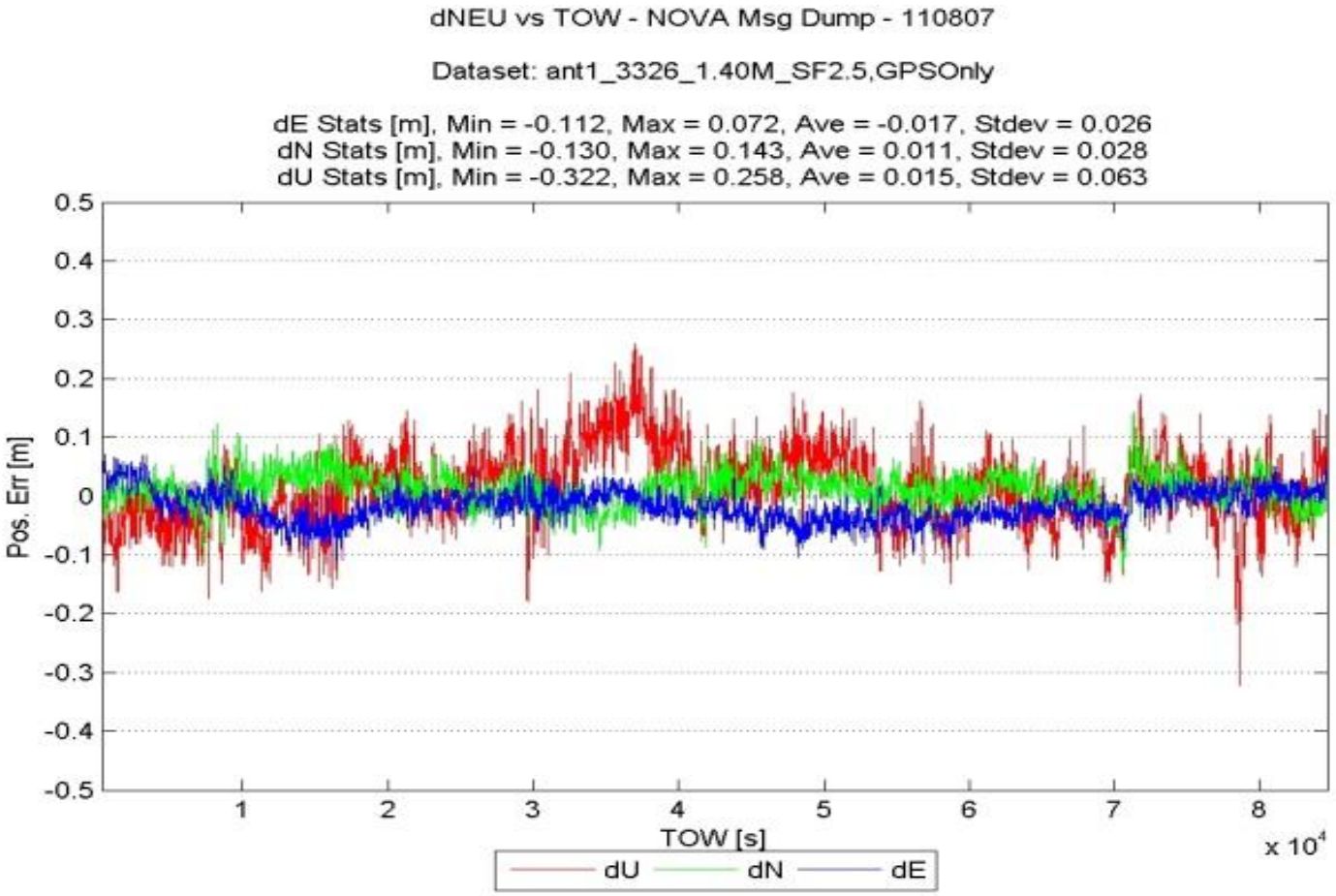
- John Deere ground reference network
- Proprietary StarFire real-time processing software – iCore
- Dual GNSS (GPS+ GLONASS) system
- 5cm horizontal accuracy globally
- Faster pull-in performance

# iCORE StarFire Processing Software

- **Innovative Clock and Orbit Real-time Estimator – iCORE**
  - Undifferenced GPS and GLONASS measurements from homogeneous SF-3050 GNSS receiver network.
  - Integrated Kalman filter estimator (GPS + GLONASS + ···)
  - DD Carrier phase ambiguities are constrained to the integer values
  -
- **Continue to modernize StarFire GNSS**

# Upgraded StarFire GNSS GPS Only

## Torrance Rooftop, Static, Open sky



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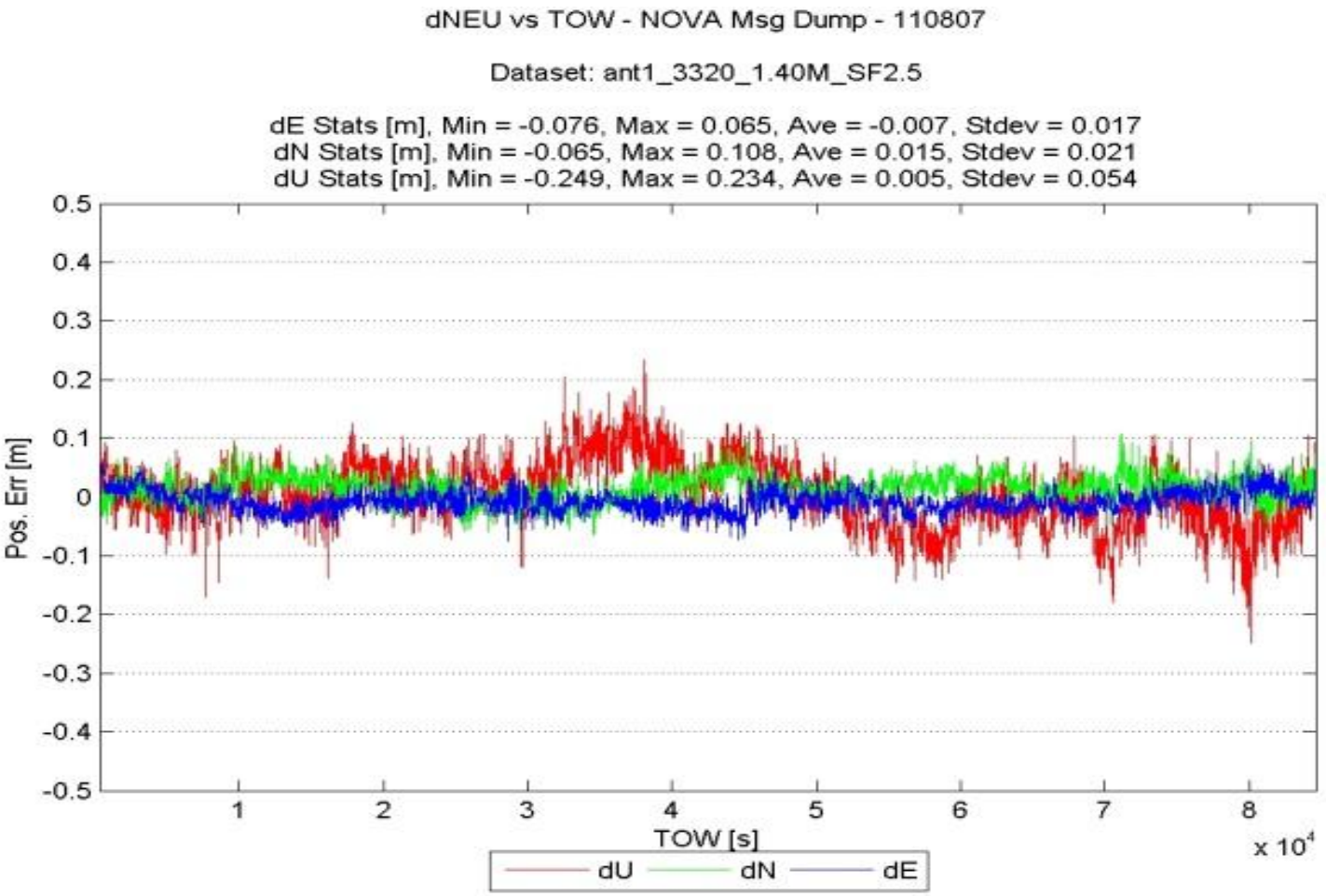
# Upgraded StarFire GNSS

## Torrance Rooftop, Static, Open sky



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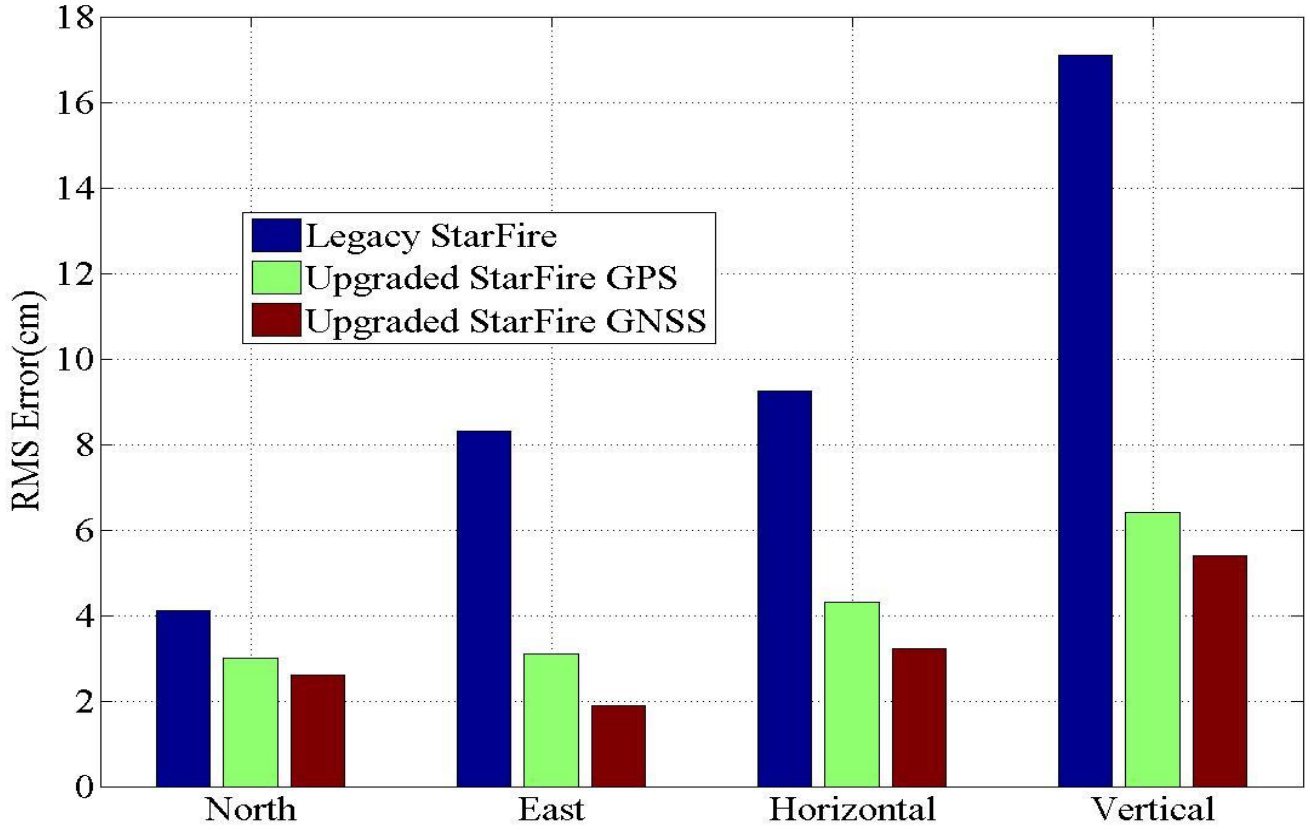
# Statistics of StarFire Position RMS



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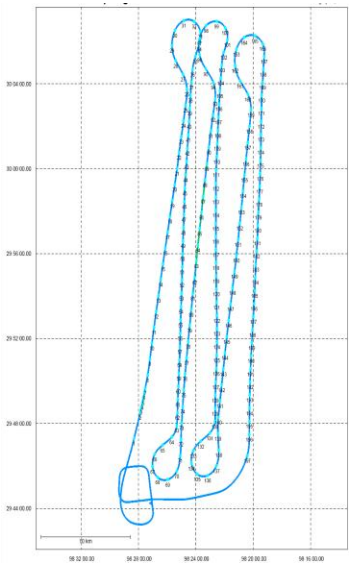
# StarFire GNSS User Benefits



## Real-Time Global Accuracy

- Less than 5cm, horizontal
- Less than 10cm, vertical
- No local base station setup and radio link
- Integrated StarFire GNSS with L-band in ONE receiver
- Global availability in real-time
- Faster convergence time

# StarFire GNSS Applications

- **Machine Guidance**
  - Agriculture
  - Construction
- **Offshore Survey**
- **Aerial Survey**
- **Autonomous Vehicles**
- **Land Survey**
- **Military**

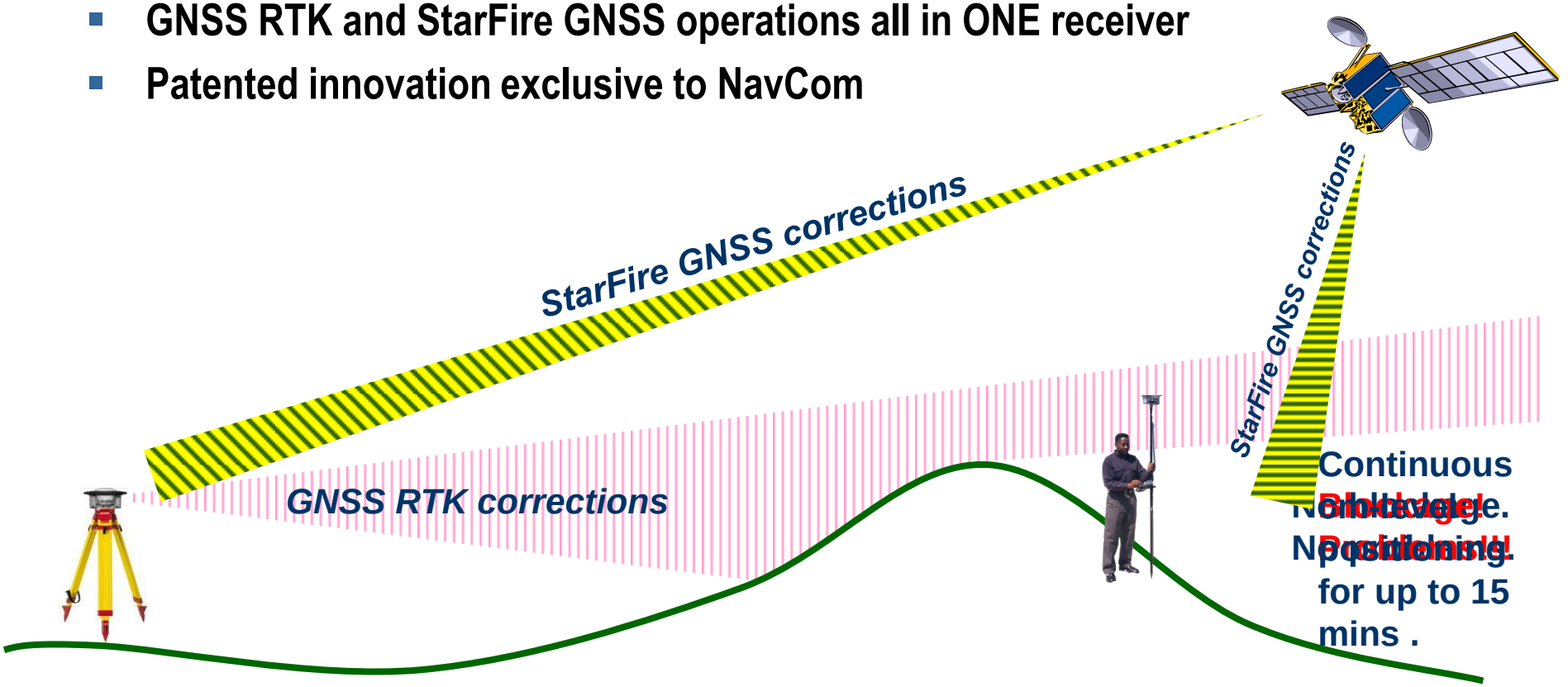




***Worldwide 5cm accuracy in real-time***

# RTK Extend

- RTK Extend bridges the gaps in GNSS RTK coverage
- GNSS RTK and StarFire GNSS operations all in ONE receiver
- Patented innovation exclusive to NavCom



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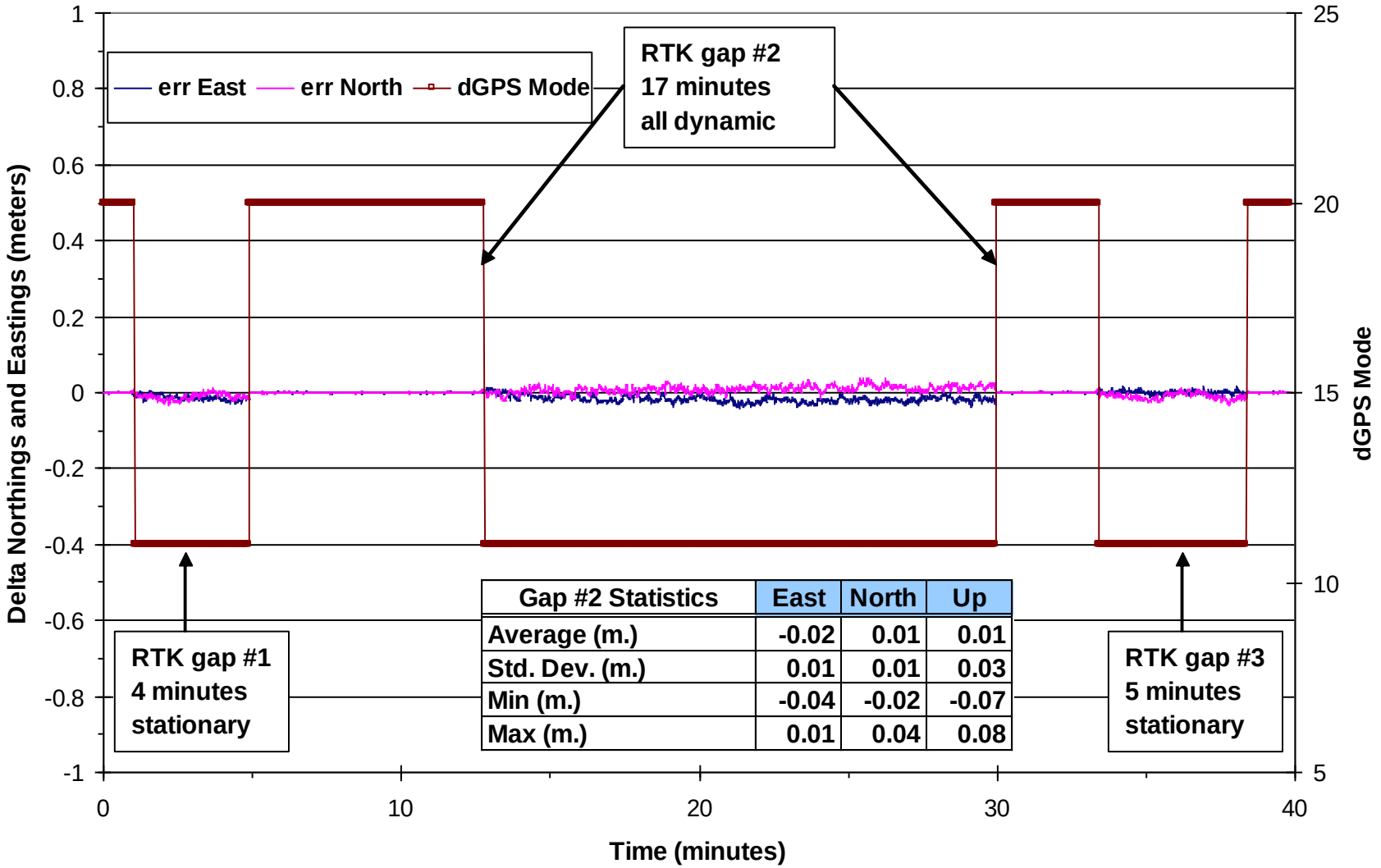
# RTK Extend Dynamic Test Results




| Gap #2 Statistics | East | North | Up |
|---|---|---|---|
| Average (m.) | -0.02 | 0.01 | 0.01 |
| Std. Dev. (m.) | 0.01 | 0.01 | 0.03 |
| Min (m.) | -0.04 | -0.02 | -0.07 |
| Max (m.) | 0.01 | 0.04 | 0.08 |



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# Summary

- The integrated StarFire GPS with GLONASS system was developed and integrated into NavCom & John Deere GNSS receiver families

- Dual global real-time StarFire solutions in one receiver
  - Legacy StarFire GPS: sub-decimeter, horizontal
  - StarFire GNSS: less than 5cm, horizontal

- Unique fusion of GNSS RTK with StarFire GNSS → RTK-extend

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