GNSS Integrity Anomaly

Simulation and Application

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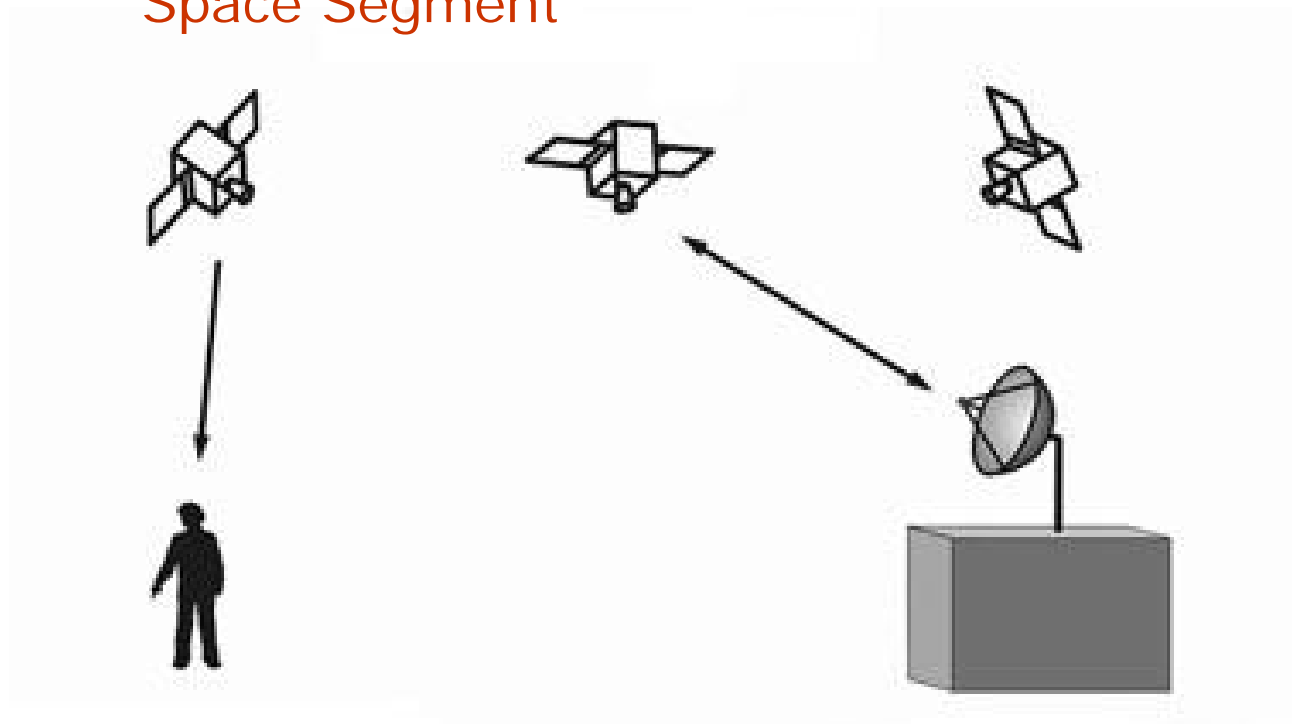wangwei4213440@163.com

Outline

- GNSS Simulation System

  ---- What we have done

- GNSS integrity anomaly simulation

  ---- What we are doing now

GNSS Simulation System

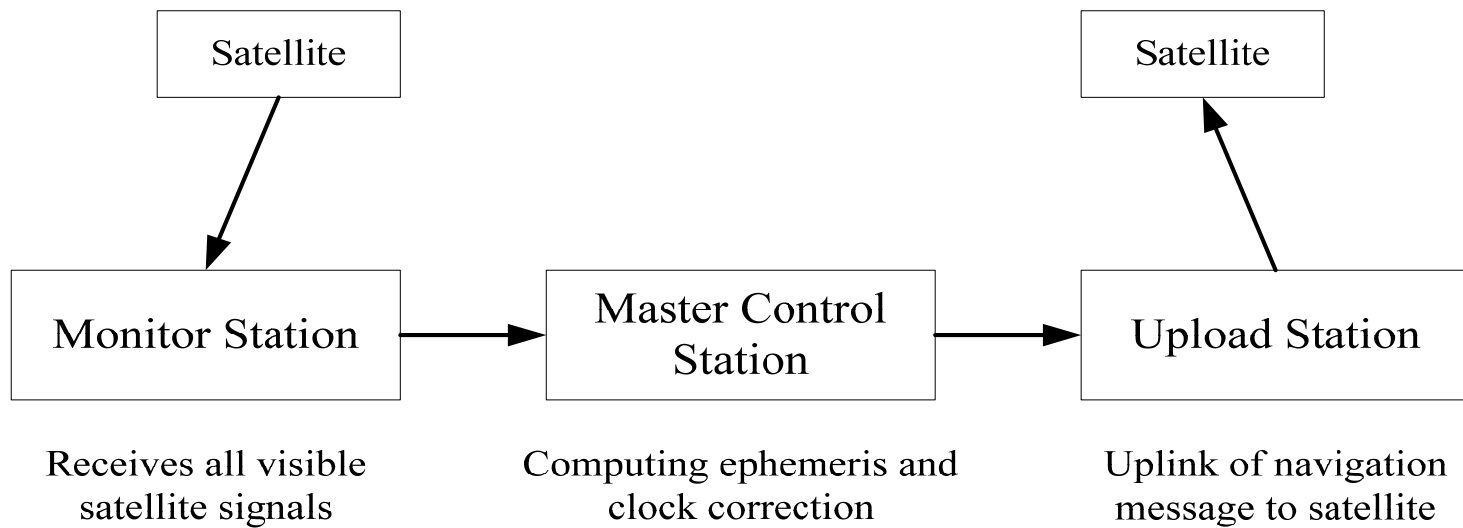Global Navigation Satellite System

Space Segment

User Segment   Ground Control Segment
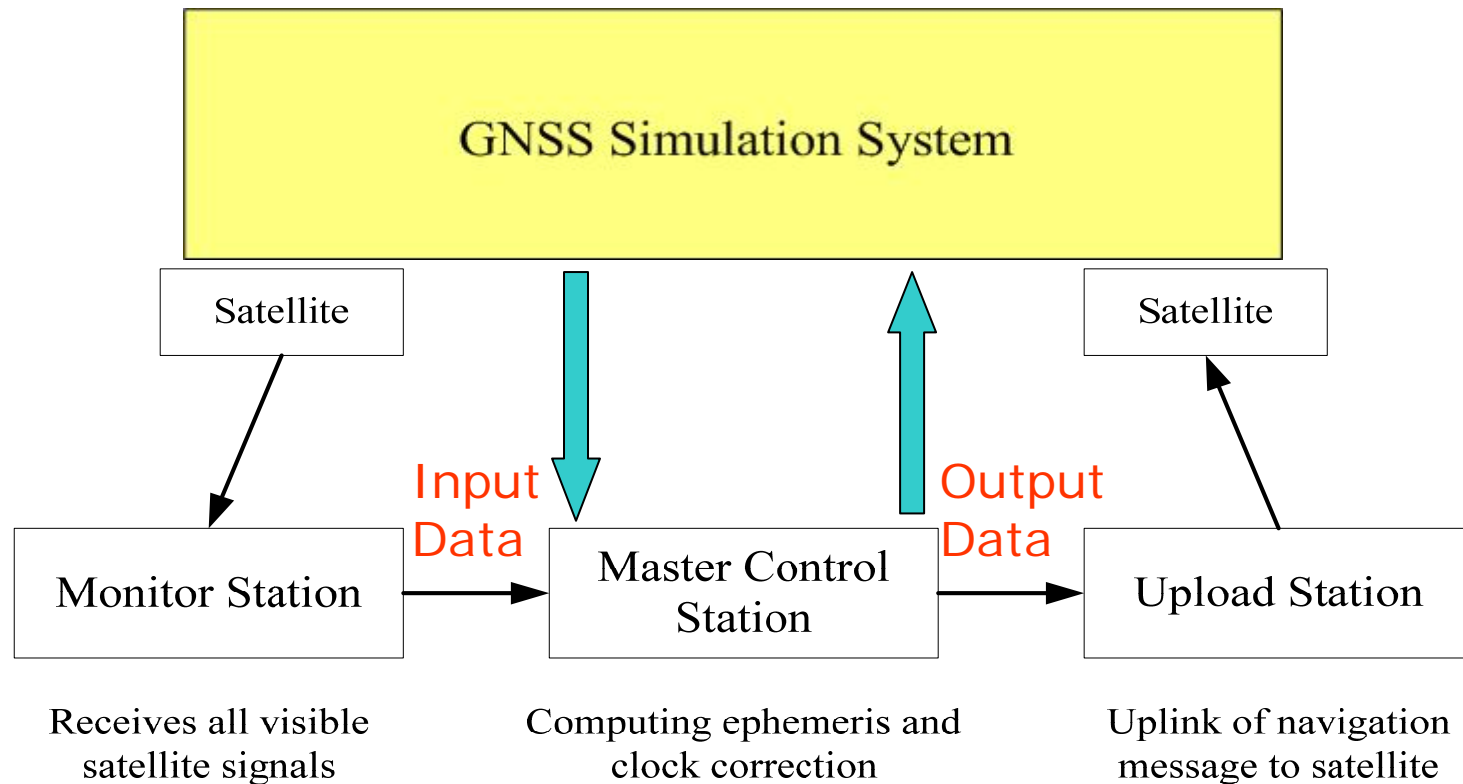
GNSS Simulation System

Global Navigation Satellite System

Data Flow in the Ground Control Segment

Satellite		Satellite

Monitor Station	→	Master Control Station	→	Upload Station

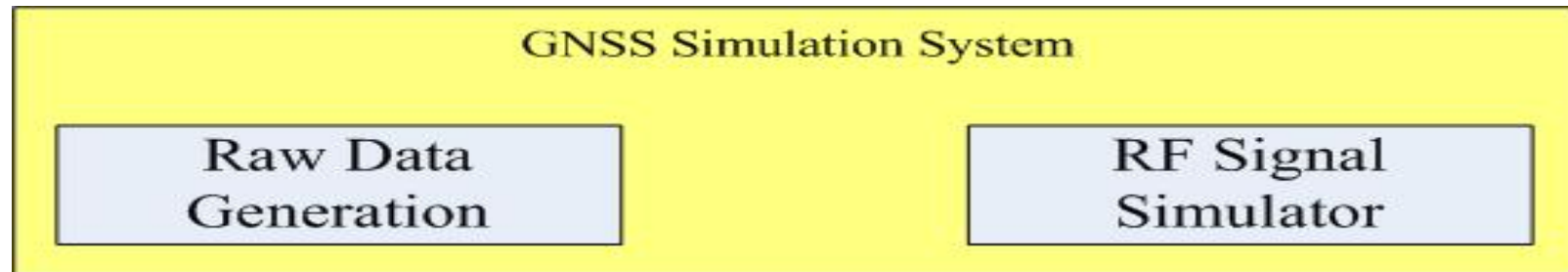| Receives all visible satellite signals	Computing ephemeris and clock correction	Uplink of navigation message to satellite

GNSS Simulation System

It is necessary to set up a simulation system to drive and test the Ground Control Segment.

GNSS Simulation System

| Satellite	Input Data	Output Data	Satellite

Monitor Station	Master Control Station	Upload Station
Receives all visible satellite signals	Computing ephemeris and clock correction	Uplink of navigation message to satellite

GNSS Simulation System

GNSS Simulation System

| Raw Data Generation | RF Signal Simulator |

- **Raw Data Generation**

  ✓ **Pseudo Range,**
     Carrier Phase,
     Doppler, etc

  ✓ **Satellite Navigation Data**

  ✓ **Date Output On-line**

  ✓ **Date Output in files**

- **RF Signal Simulation**

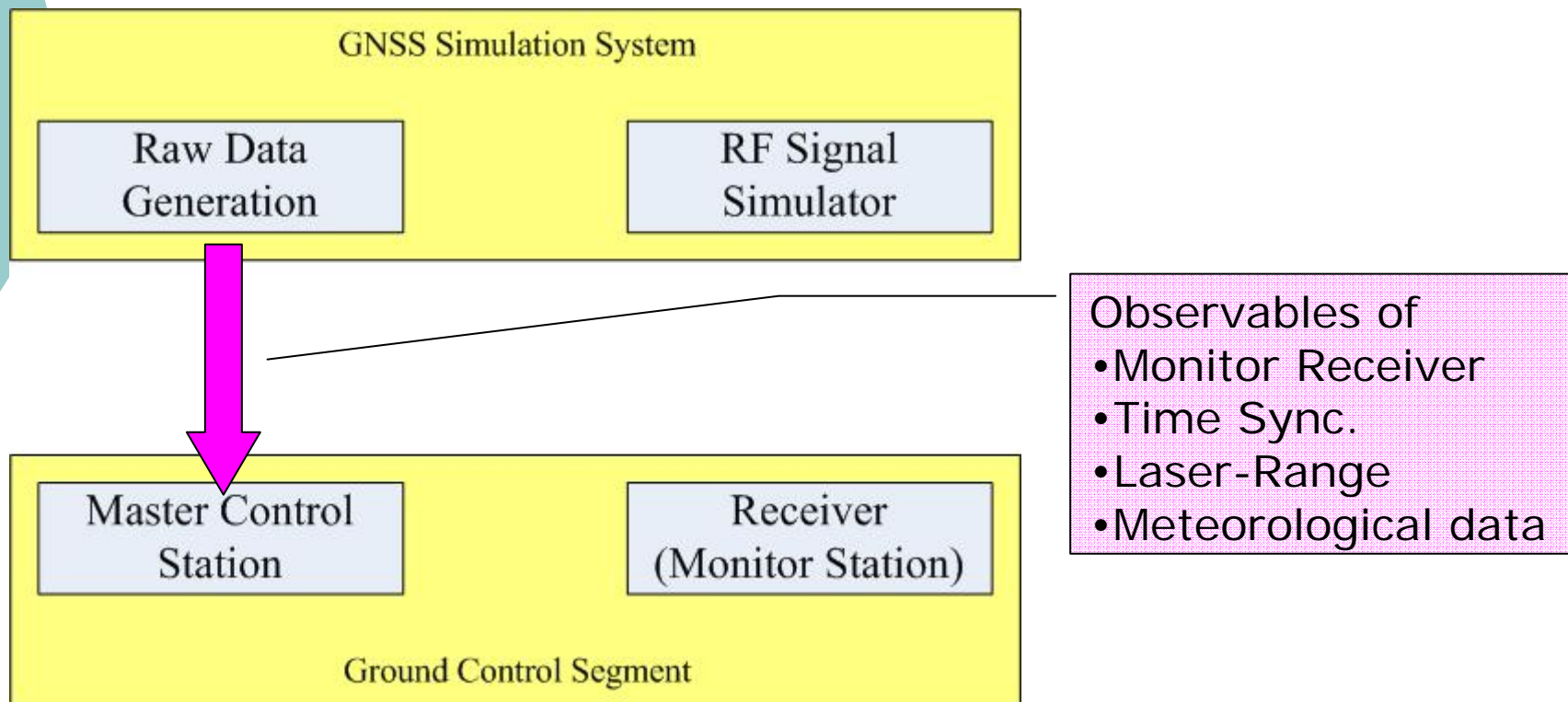 ✓ **Different Carrier frequency**

  ✓ **Different Pseudo Range Code**

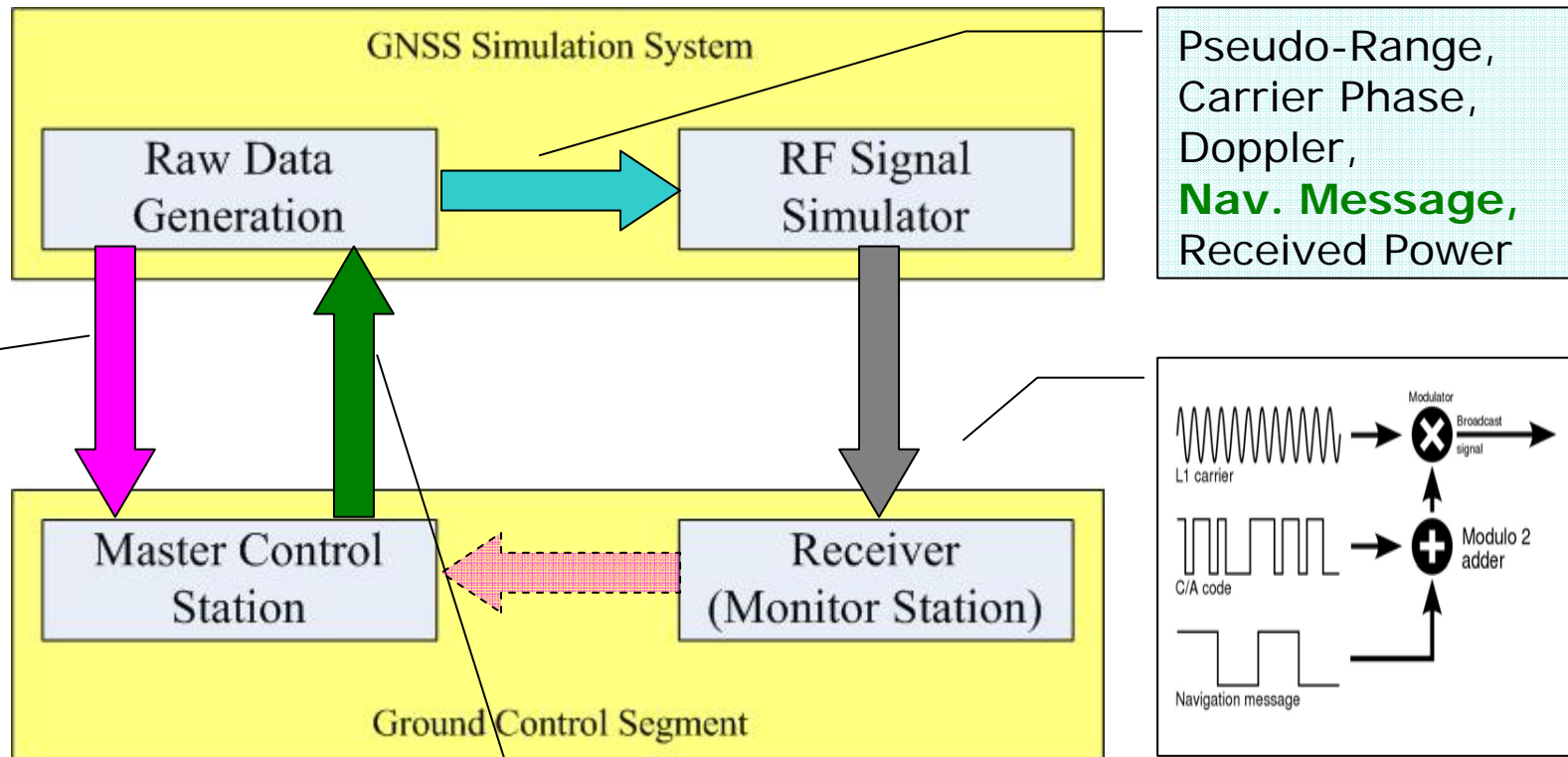# GNSS Simulation System

Test of Receiver (RF Mode)

Pseudo-Range,
Carrier Phase,
Doppler,
NAV Message,
...
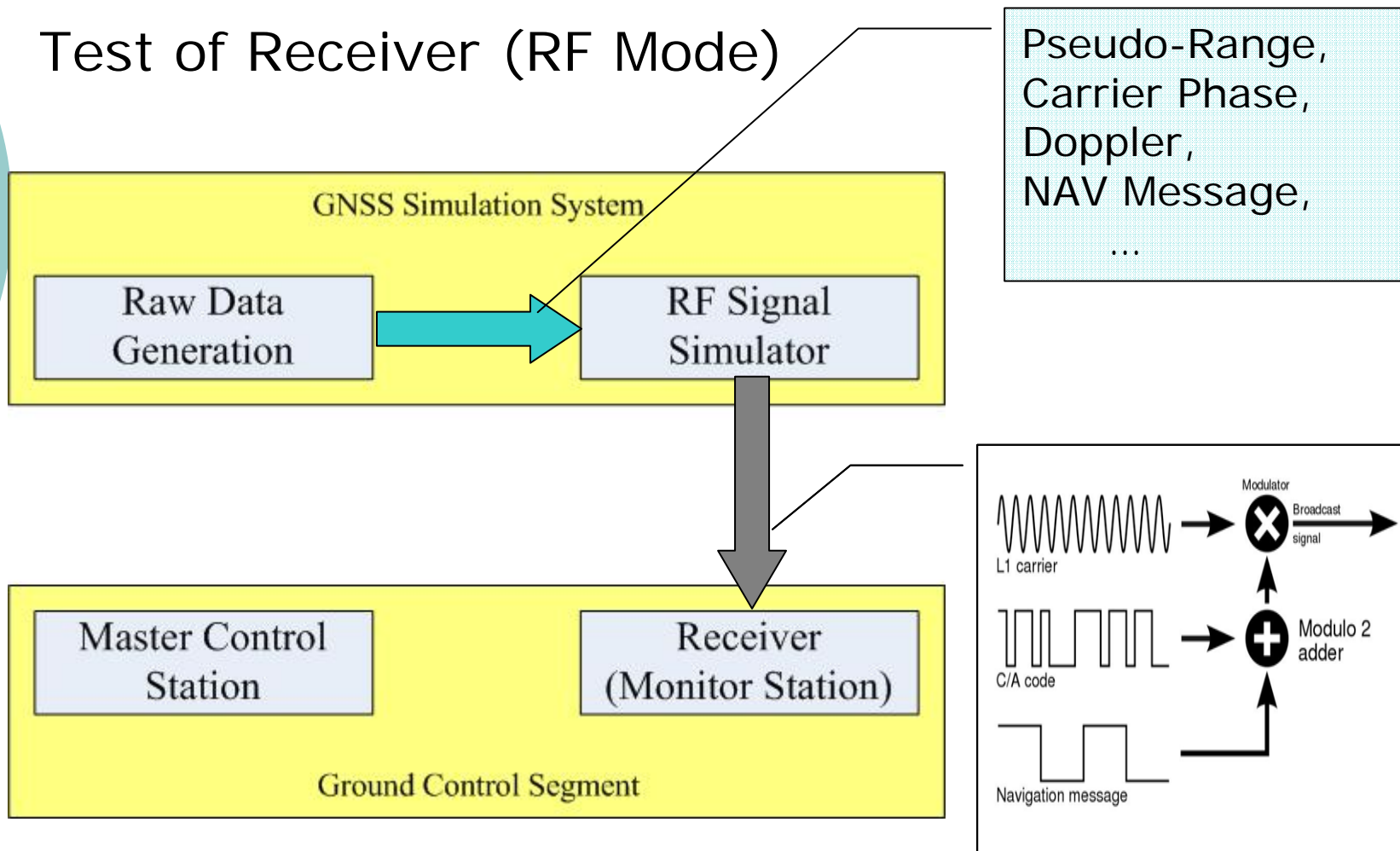
GNSS Simulation System

Test of Master Control Station (Data Mode)

GNSS Simulation System

Raw Data Generation

RF Signal Simulator

Master Control Station

Receiver (Monitor Station)

Ground Control Segment

Observables of
• Monitor Receiver
• Time Sync.
• Laser-Range
• Meteorological data

GNSS Simulation System

Test of Master Control Station and Receiver (Mixed Mode)

Pseudo-Range, Carrier Phase, Doppler, **Nav. Message**, Received Power

GNSS Simulation System
- Raw Data Generation
- RF Signal Simulator

Ground Control Segment
- Master Control Station
- Receiver (Monitor Station)

Observations
•Monitor Receiver
•Time Sync.
•Laser-Range
•Meteorological data

• Navigation Messages
• Commands of Mission Planning and Schedule

GNSS Simulation System

- complex , flexible and high fidelity

- oriented to Master Control Station and Receiver test

- support MCS real-time closed-loop test

- further research work is continued

    ---- Integrity Anomaly Simulation

GNSS integrity anomaly simulation

- GNSS integrity anomalies is unreported anomalous behaviors affecting user performance

- Although integrity anomalies are rare events, they do occur.

- GNSS integrity anomaly simulation activity

  - ➢ collecting integrity anomaly observations
  - ➢ analyzing the causes and effects
  - ➢ determining integrity anomaly models
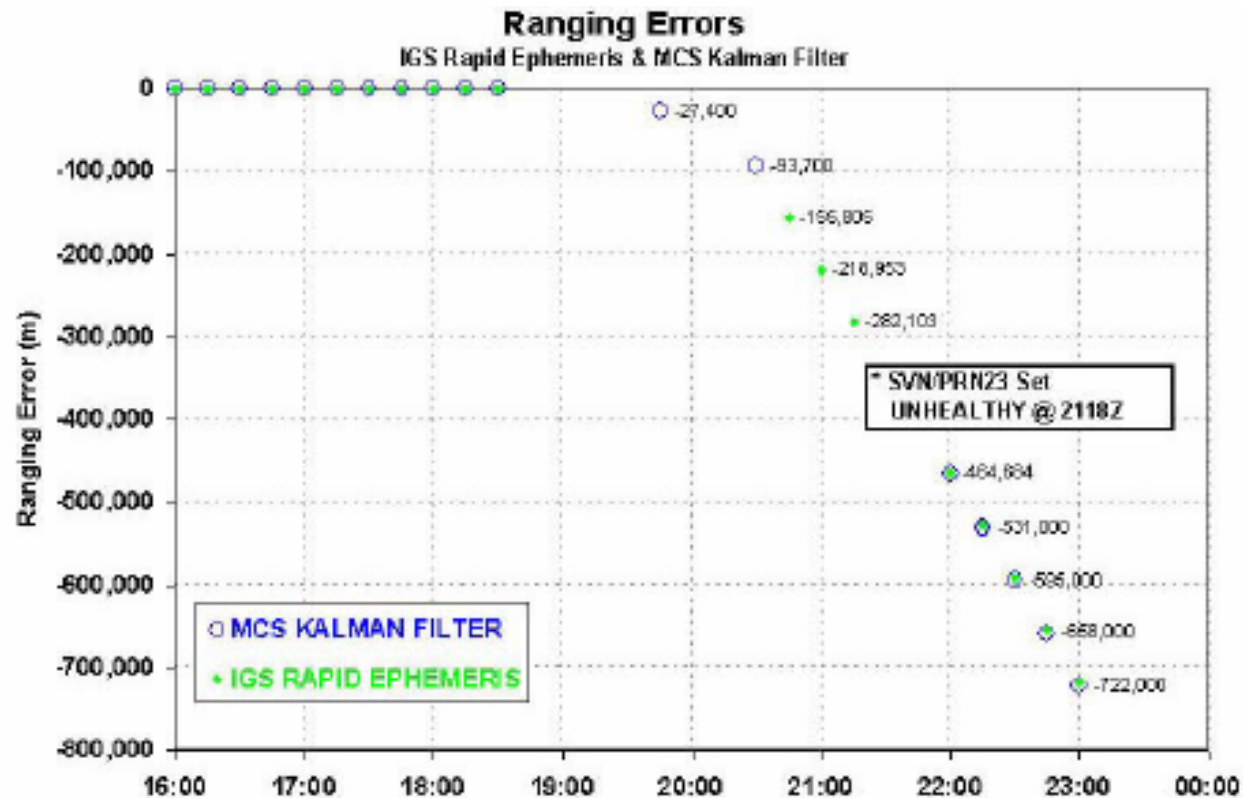 - ➢ creating integrity anomaly database

GNSS integrity anomaly simulation

• **Anne-Laure Vogel etc. Effect of a GPS Anomaly on Different GNSS Receivers. ION GNSS 18th International Technical Meeting of the Satellite Division, 13-16 September 2005, Long Beach, CA**
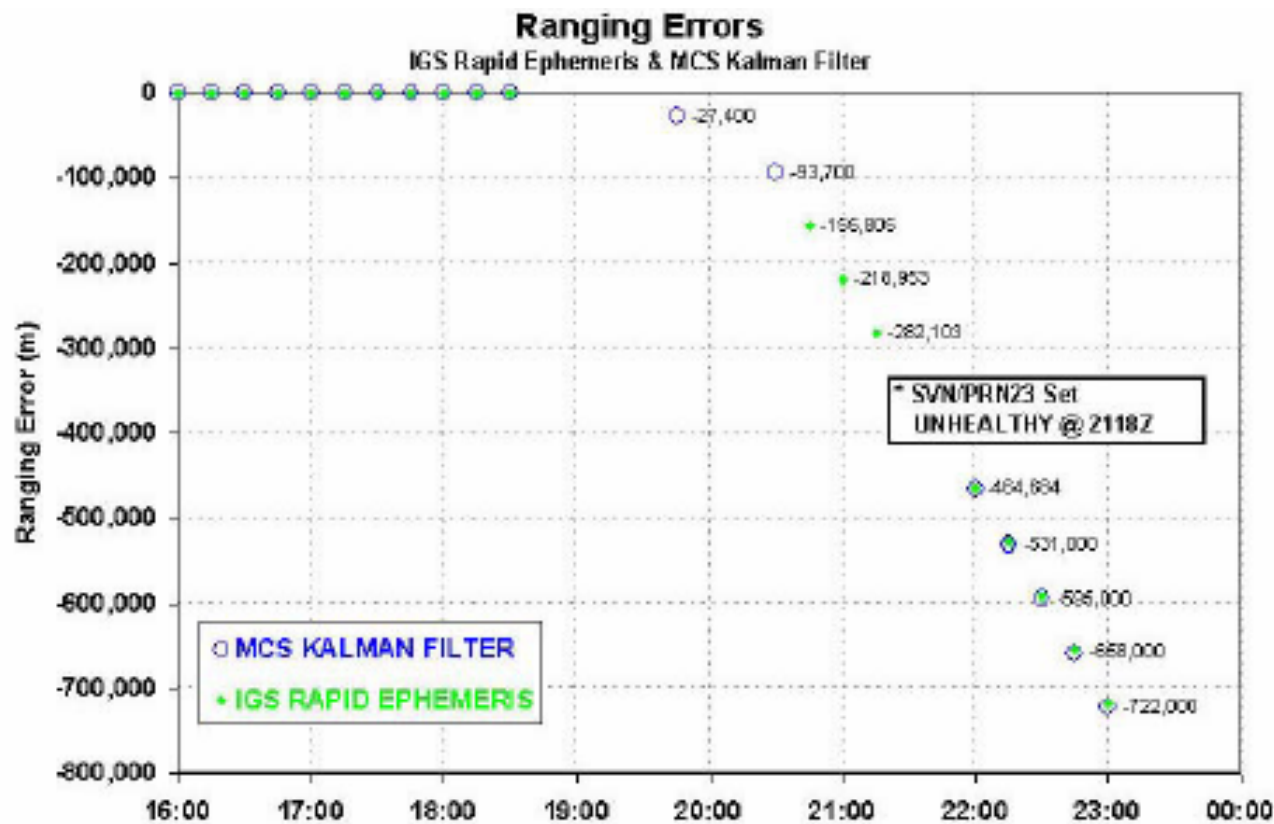
Pseudo-range error on the PRN 23
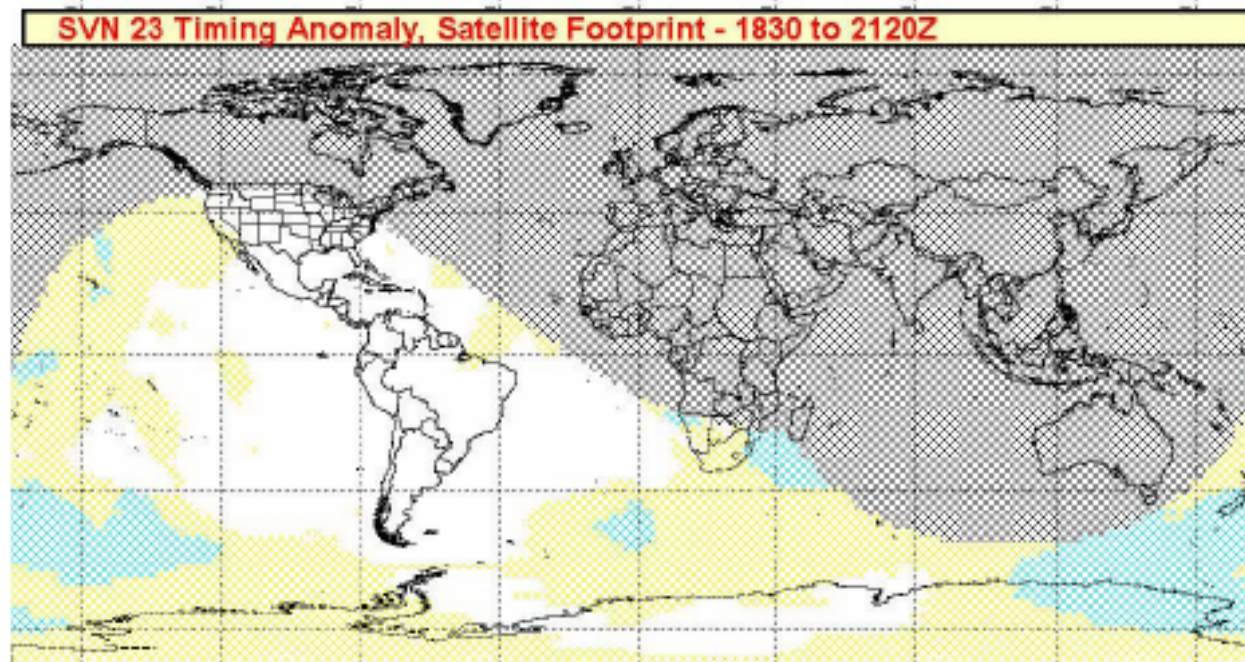
GNSS integrity anomaly simulation

- occurred on January 1, 2004
- starting at around 18h30 UTC
- declared unusable at 21h18 UTC

A failure of the atomic clock system (ramp)

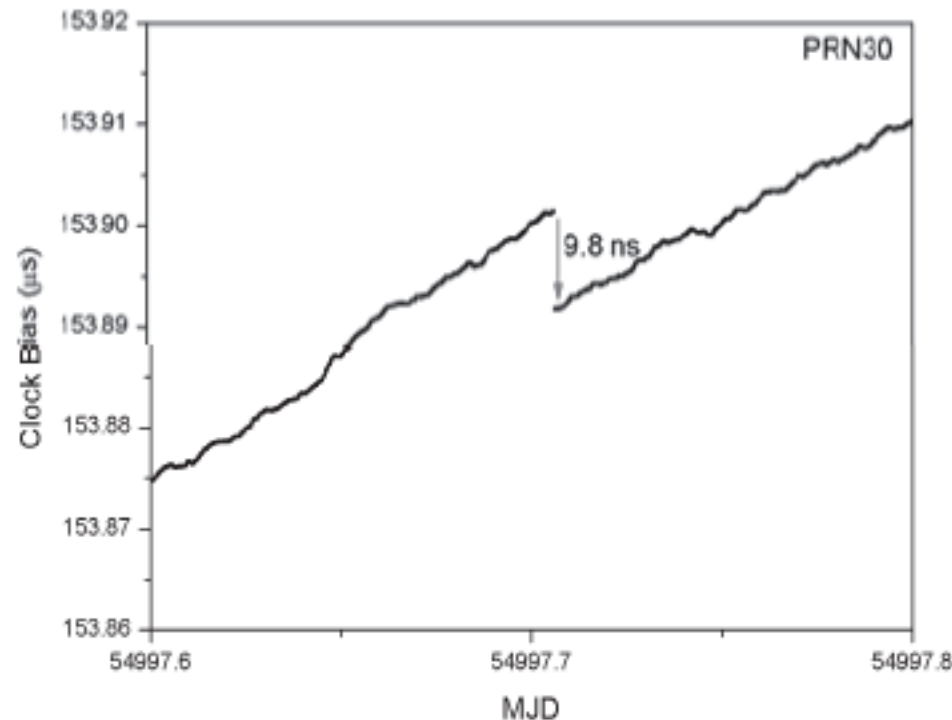# GNSS integrity anomaly simulation

SVN 23 Timing Anomaly, Satellite Footprint - 1830 to 2120Z

Affected area shown in gray
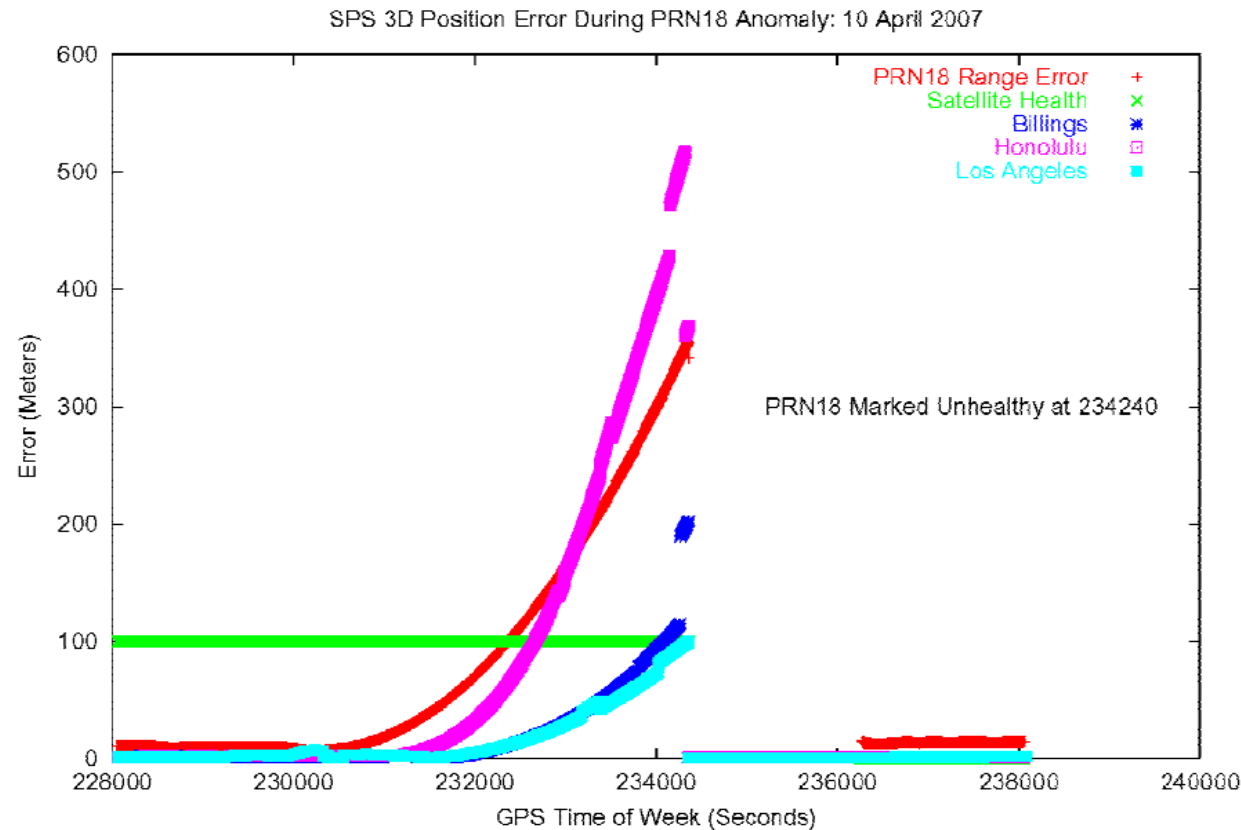
GNSS integrity anomaly simulation

On June 21, 2009, PRN30 had a drift of approximately 250 ns during the day, a jump of approximately 9.8 ns occurred on MJD 54997.71.

A failure of the atomic clock system (jump)

GNSS integrity anomaly simulation

• **Nathan Vary, GPS Satellite PRN18 Anomaly Affecting SPS Performance, WASS Technical Report, William J. Hughes Technical Center, Pomona, New Jersey, 4/11/2007**
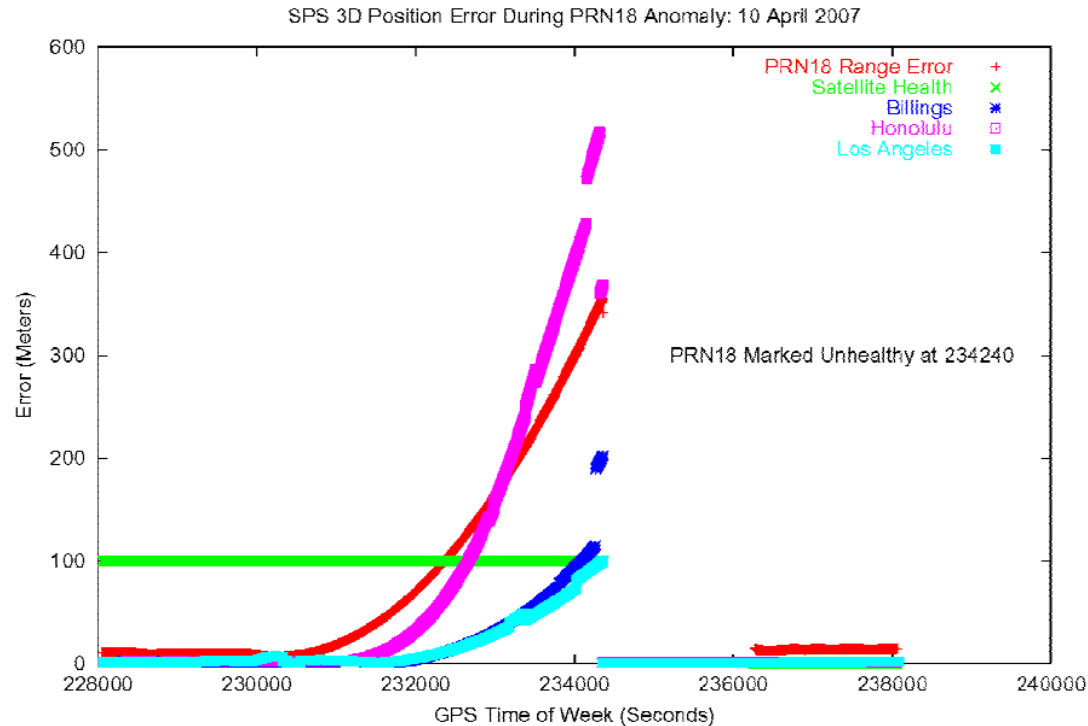
SPS 3D Position Error During PRN18 Anomaly: 10 April 2007

April 10, 2007 GPS satellite PRN18 suffered a maintenance anomaly.

range errors

GNSS integrity anomaly simulation

SPS 3D Position Error During PRN18 Anomaly: 10 April 2007

The satellite was supposed to be set unhealthy before maintenance.

The satellite health bit was not set 'unhealthy' prior to the maintenance.

This resulted in severe range errors at all sites tracking the satellite between 15:53 and 17:04 GMT when it was finally set to unhealthy.

GNSS integrity anomaly simulation

• **NIELS JONKMAIU and KEES DE JONG. Integrity Monitoring of IGEX-98 Data—Part III: Broadcast Navigation Message Validation. GPS Solutions, Vol. 4, No. 2, pp. 45-53 (2000)**

TABLE 3

Navigation messages of GLONASS slots 7 and 13, extracted from RINEX GLONASS navigation files. The message of slot 7 shows an example of the accidental zeroing out of all ephemeris parameters; the message of slot 13 shows an example of the zeroing out of all clock parameters. The satellite in slot 7 detects the problem, and the health flag is raised (last parameters on the second line of the message, 1 = unhealthy). The health flag is not raised in the message of slot 13.

Navigation message slot 7, 3 December 1999, 7:15:00.0 UTC

7	99 12 3 7 15 0.0	.195056200027D−04	−.272848410532D−11	.261000000000D+05
	.000000000000D+00	.000000000000D+00	.000000000000D+00	.100000000000D+01
	.000000000000D+00	.000000000000D+00	.000000000000D+00	.700000000000D+01
	.000000000000D+00	.000000000000D+00	.000000000000D+00	.000000000000D+00

Navigation message slot 13, 19 July 1999, 3:45:00.0 UTC

13	99 7 19 3 45 0.0	.000000000000D+00	.000000000000D+00	.135000000000D+05
	.437475048828D+04	.305475997925D+01	.000000000000D+00	.000000000000D+00
	−.111685366211D+05	−.390982627869D+00	.931322574615D−09	.600000000000D+01
	.225473310547D+05	−.781626701355D+00	−.186264514923D−08	.000000000000D+00

Broadcast Navigation Message Error

GNSS integrity anomaly simulation

TABLE 2

Navigation messages of GLONASS slots 9 and 15, extracted from RINEX GLONASS navigation files. The messages show the change of the satellite clock parameters for slot 9 to incorrect values, probably those of slot 15, as well as the change back to correct values. Note that the first line of the messages consists of slot number, ephemeris reference date and time, satellite clock offset and drift and message frame time. The message frame time indicates the start of transmission of the navigation data in seconds of the current day. For a complete description of the message format, the reader is referred to Gurtner (1998).

Navigation messages slot 15, 17 November 1998, 5:15:00.0 UTC

15	98 11 17 5 15 0.0	.609150156379D−04	−.545696821064D−11	.189000000000D+05
	−.172614697266D+04	−.232635688782D+01	.000000000000D+00	.000000000000D+00
	.122101513672D+05	−.198976612091D+01	.000000000000D+00	.400000000000D+01
	.223212856445D+05	.900071144104D+00	−.279396772385D−08	.200000000000D+01

Navigation messages slot 9, 17 November 1998, 21:45:00.0 UTC

9	98 11 17 21 45 0.0	.141195021570D−03	.909494701773D−12	.774000000000D+05
	.167495493164D+05	.131936454773D+01	.186264514923D−08	.000000000000D+00
	−.153474038086D+05	−.891745567322D+00	.279396772385D−08	.600000000000D+01
	.115610678711D+05	−.309737873077D+01	.000000000000D+00	.100000000000D+01
9	98 11 17 21 45 0.0	.606160610914D−04	−.545696821064D−11	.783000000000D+05
	.167495493164D+05	.131936454773D+01	.186264514923D−08	.000000000000D+00
	−.153474038086D+05	−.891745567322D+00	.279396772385D−08	.600000000000D+01
	.115610678711D+05	−.309737873077D+01	.000000000000D+00	.100000000000D+01

Navigation messages slot 9, 18 November 1998, 6:15:00.0 UTC

| 9	98 11 18 6 15 0.0	.604558736086D−04	−.636646291241D−11	.216000000000D+05
	.732894531250D+04	−.251509761810D+01	.000000000000D+00	.000000000000D+00
	.136082358398D+05	−.118695259094D+01	.931322574615D−09	.600000000000D+01
	.202994682617D+05	.170007801056D+01	−.279396772385D−08	.100000000000D+01
9	98 11 18 6 15 0.0	.141248106956D−03	.181898940355D−11	.225000000000D+05
	.732894531250D+04	−.251509761810D+01	.000000000000D+00	.000000000000D+00
	.136082358398D+05	−.118695259094D+01	.931322574615D−09	.600000000000D+01
	.202994682617D+05	.170007801056D+01	−.279396772385D−08	.100000000000D+01

GNSS integrity anomaly simulation

- Satellite Vehicles (SVs) clock failure

    clock ramp/jump

- Satellite Vehicles (SVs) orbit change

    satellite maneuver/maintenance

- Operational Control System (OCS) blunder

    navigation messages error

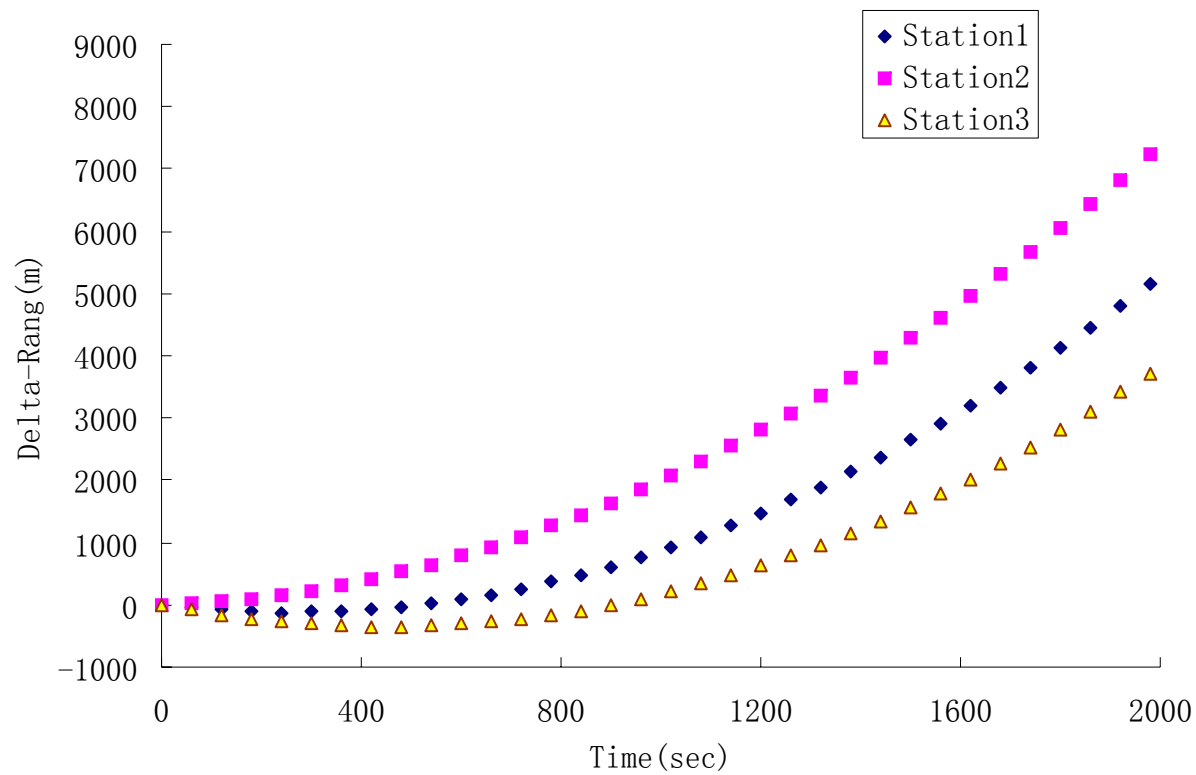# GNSS integrity anomaly simulation

- Satellite Vehicles (SVs) clock failure   (clock ramp/jump)
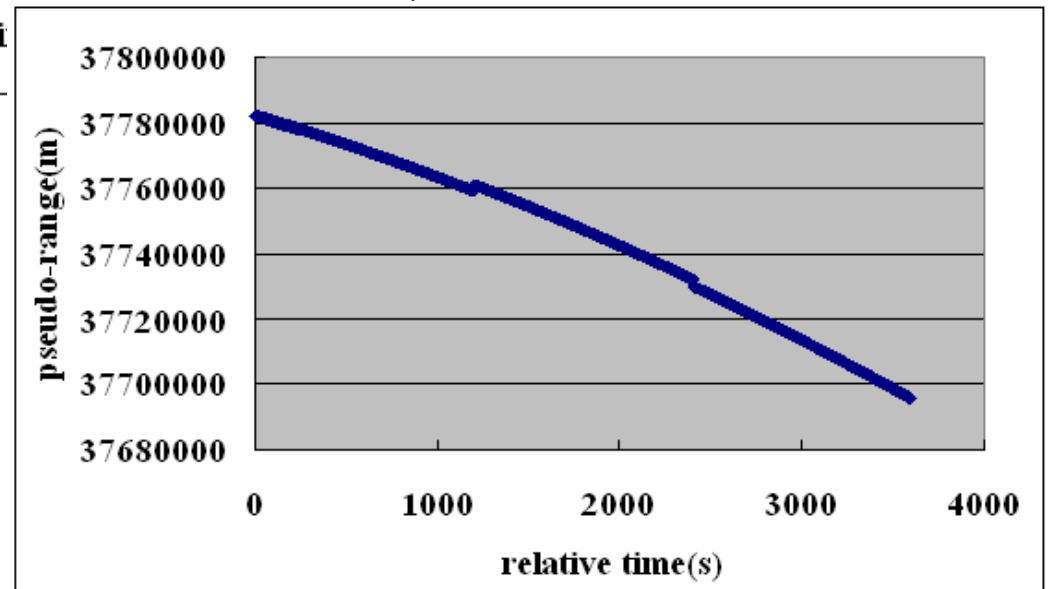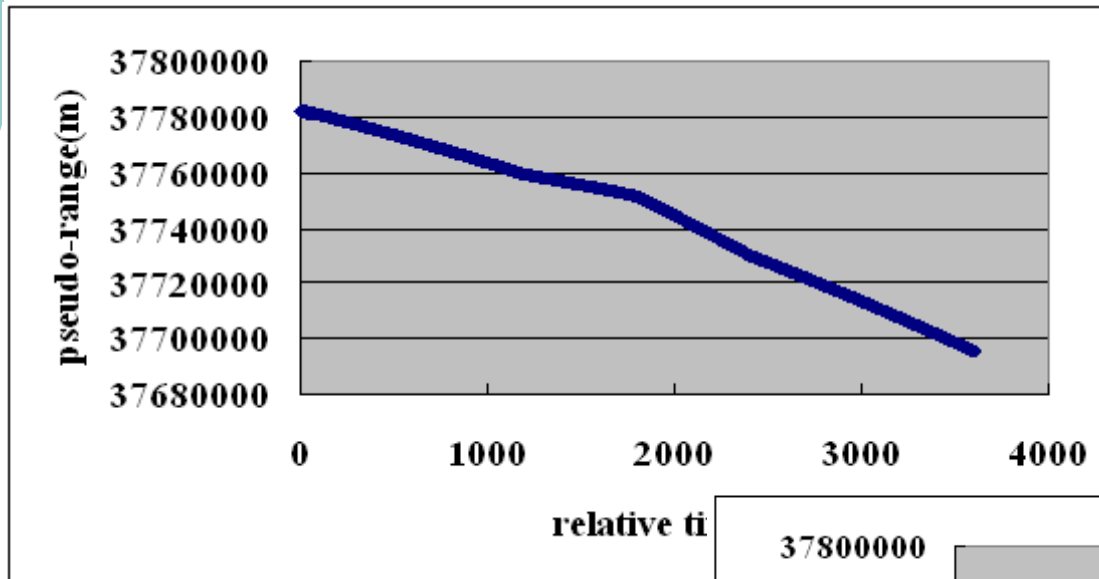
GNSS integrity anomaly simulation

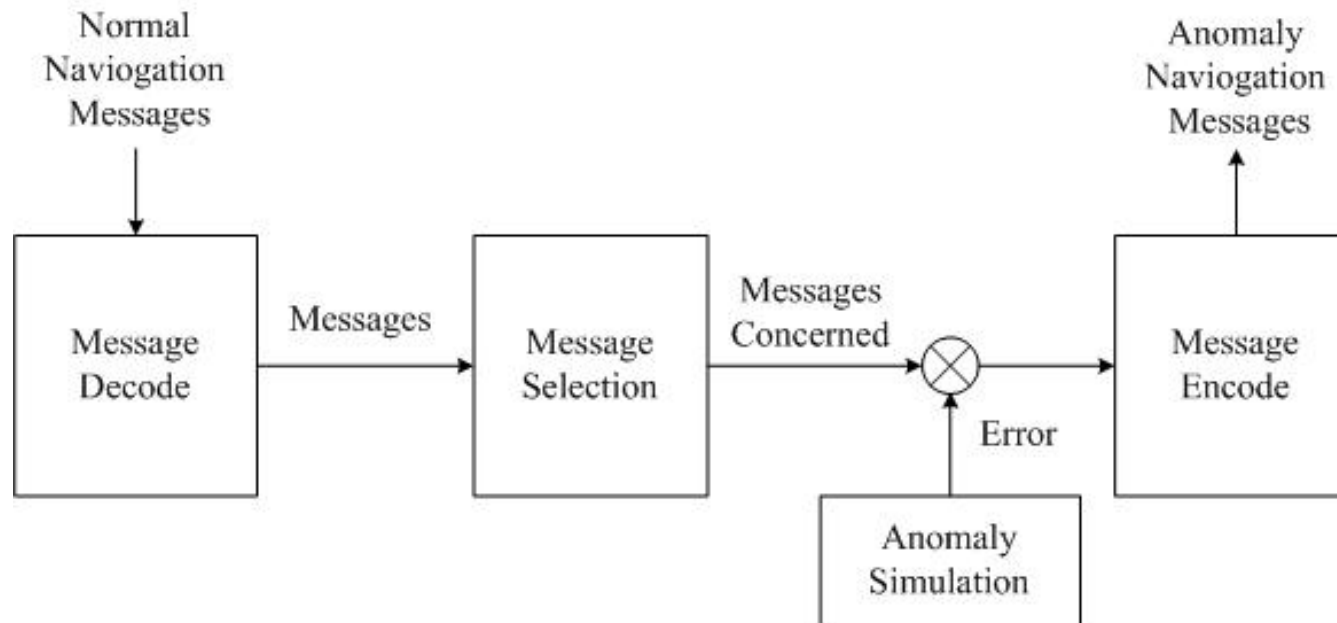- Satellite Vehicles (SVs) orbit change

satellite maneuver/maintenance

GNSS integrity anomaly simulation

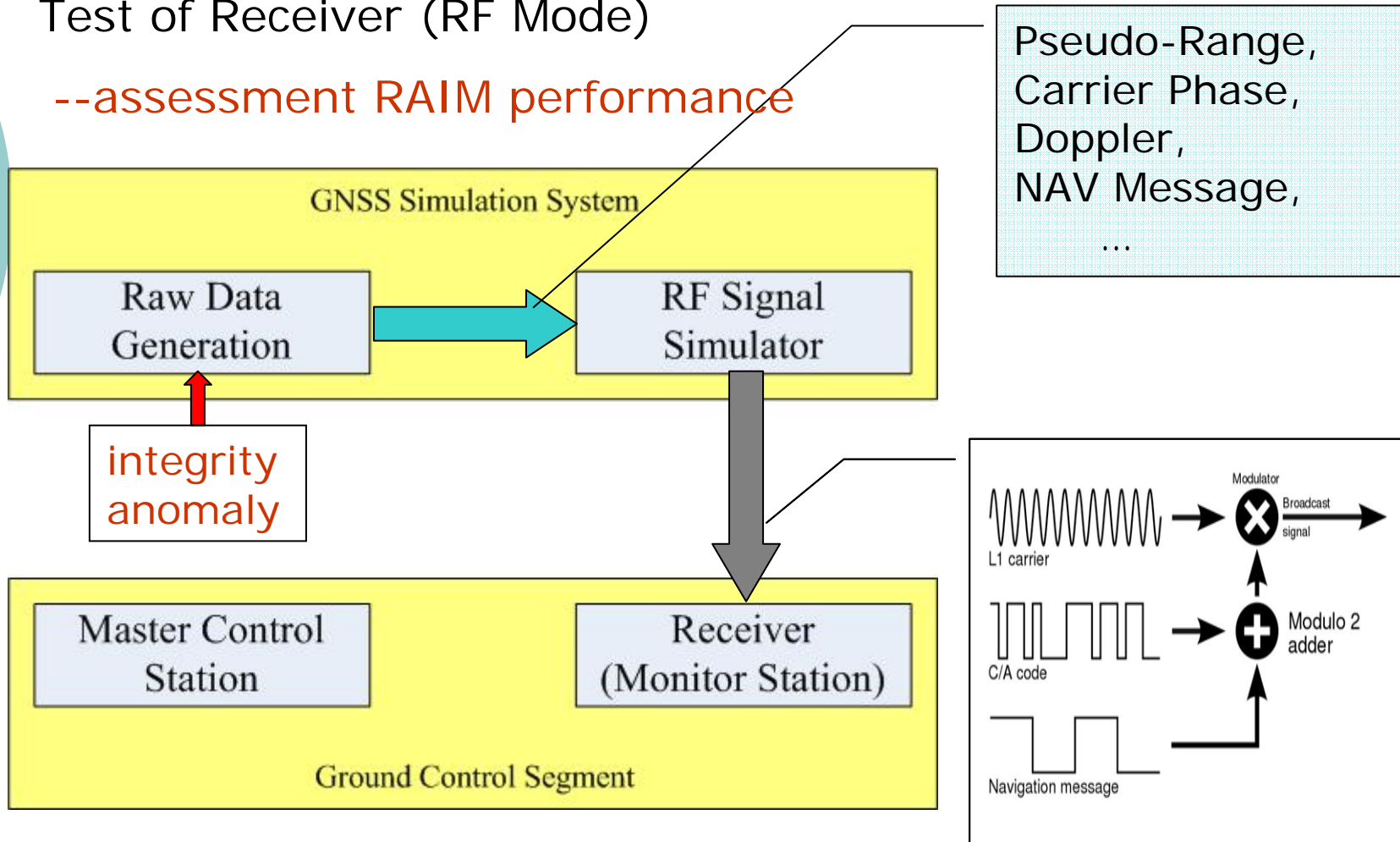- Operational Control System (OCS) blunder

  navigation messages error

GNSS Simulation System

Test of Receiver (RF Mode)

--assessment RAIM performance

Pseudo-Range,
Carrier Phase,
Doppler,
NAV Message,
...

GNSS Simulation System

Raw Data Generation → RF Signal Simulator

integrity anomaly

Master Control Station

Receiver (Monitor Station)

Ground Control Segment

Modulator

L1 carrier

Broadcast signal

C/A code
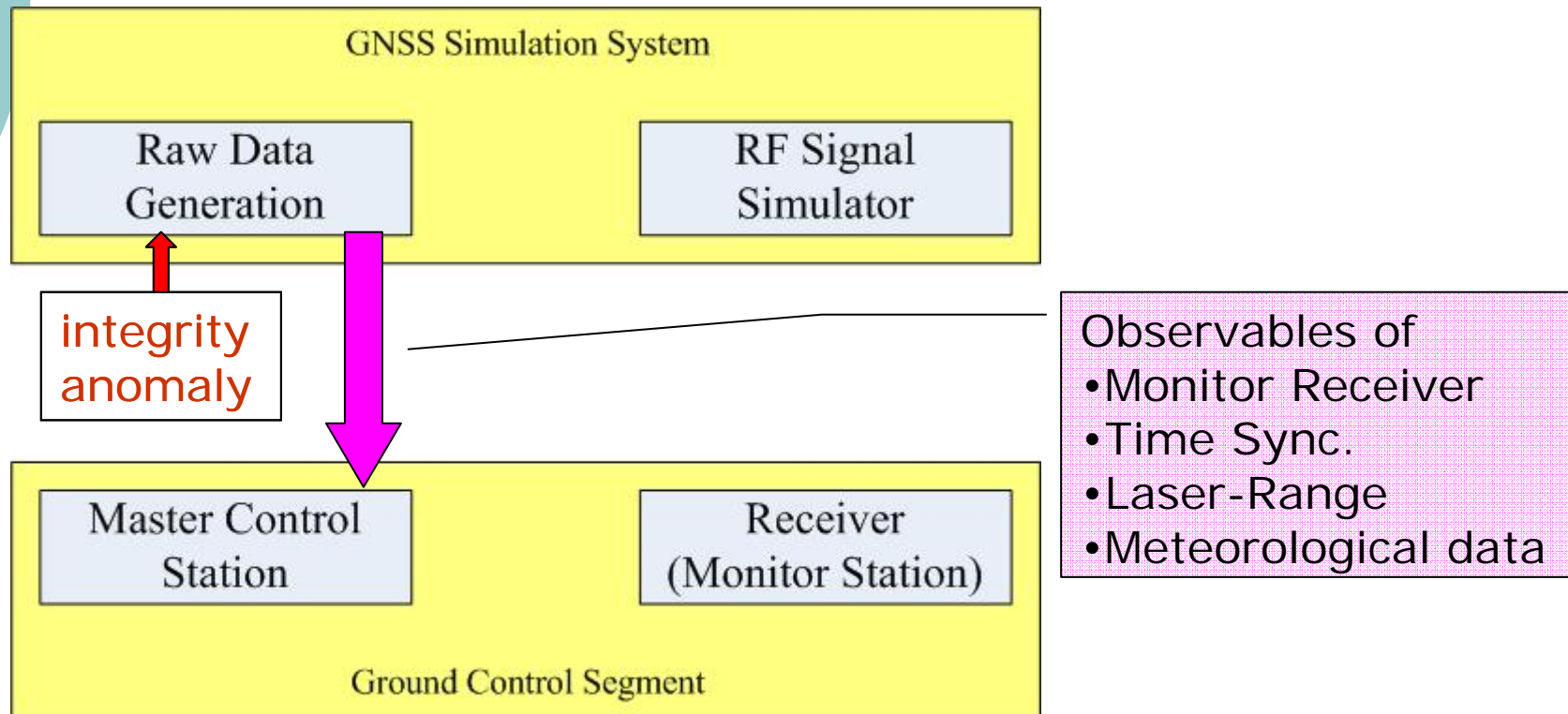
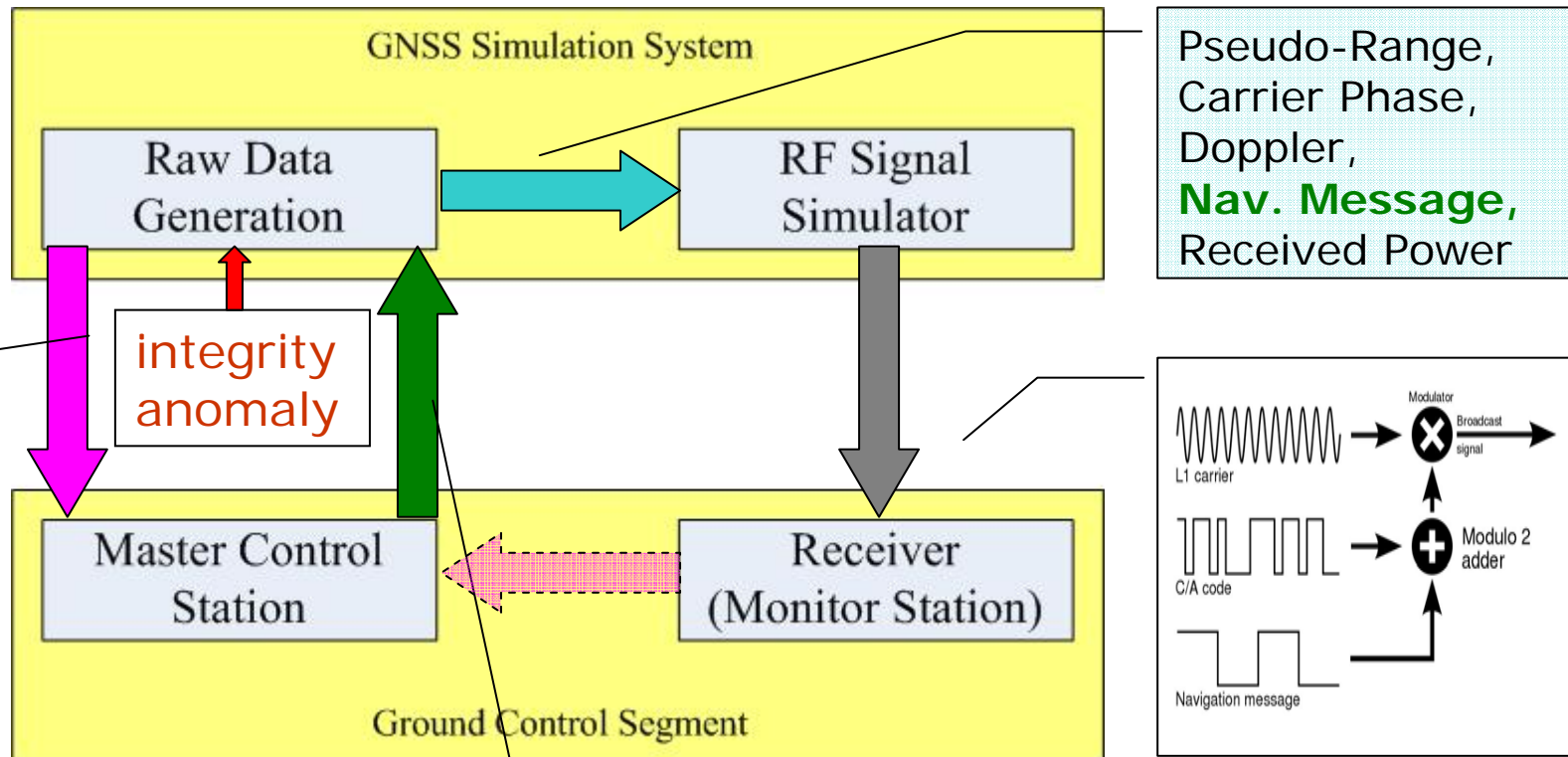Modulo 2 adder

Navigation message

GNSS Simulation System

Test of Master Control Station (Data Mode)

--assessment Ground Integrity Monitoring (GIM) performance

GNSS Simulation System

Test of Master Control Station and Receiver (Mixed Mode)

GNSS Simulation System

Raw Data Generation → RF Signal Simulator

integrity anomaly

Pseudo-Range,
Carrier Phase,
Doppler,
Nav. Message,
Received Power

Master Control Station ← Receiver (Monitor Station)

Ground Control Segment

Modulator
Broadcast signal
L1 carrier
C/A code
Modulo 2 adder
Navigation message

Observations
•Monitor Receiver
•Time Sync.
•Laser-Range
•Meteorological data

• Navigation Messages
• Commands of Mission Planning and Schedule

Summary

- A GNSS Simulation System was built for the assessment of Master Control Station and receiver

- Several integrity anomalies have been simulated, and the simulated data can be used to do the function verification and algorithm assessment of GIM and RAIM.

- The effort is continuing with the integrity anomaly data collection activities.

Thank You