# Checkout System for Aircraft Tests of GAINS: Design decisions and Lessons learned

Jaya G. Nair, C. Radhakrishna Pillai, S. Hemachandran, Dr. P. P. Mohan Lal
ISRO Inertial Systems Unit, Indian Space Research Organisation,
Vattiyoorkavu, Thiruvananthapuram
g_jaya@vssc.gov.in

***Abstract:***
*Tests aboard an aircraft were planned to validate an aided navigation system and needed the design of a rugged integrated checkout system to facilitate the operations. The environment of use, the complex functional requirements and the tight schedule for realization posed challenges. A number of design decisions made during the realization of the checkout system yielded rich dividends surpassing the expectations in certain cases. This paper examines these factors in the design to find out the lessons learned.*

*Key words: GAINS, checkout system, reference system,*

## I. INTRODUCTION

Development of a GPS-Aided navigation system (GAINS) was undertaken to obtain the capability of a precise navigation systems for use with advanced missions. GAINS combine RESINS (Redundant Strap-down Inertial Navigation System) and GPS (Global Positioning System) data for obtaining the navigation solution. During the development, tests aboard an aircraft were planned at NRSA, for performance evaluation of GAINS under aircraft flight environment and to get confidence for using GAINS for future missions. The test setup used a reference navigation system along with GAINS. Tests were planned to be conducted during a number of sorties of the aircraft to simulate different flight conditions.

An integrated checkout system which automates the requirements of tests and data processing was needed to facilitate this test. The checkout system had to provide the interfaces to interact with RESINS, GAINS and the reference navigation system. There were special challenges due to the environment of usage inside the aircraft and the tight schedule. A number of design decisions were made to realize these requirements. It turned out that some of the decisions acted as enablers, yielding results that were beyond the expectations. This paper examines these design decisions, bringing out the lessons learned.

The requirements of the checkout system are discussed first in section II followed by design details in section III. The design decisions are examined in detail in section IV followed by a discussion of implementation in section V. Conclusions follow in section VI.

## II. REQUIREMENTS TO CHECKOUT SYSTEM

Fig [1] shows the test configuration. RESINS in single chain configuration was used for the tests. Figure shows Mark-3 ISU (Inertial Sensing Unit) connected to Navigation Interface Module (NIM) and i960-based Navigation Guidance and Control Processor (NGCP). The two processors are connected to Mil-1553 bus (N-bus) where i960-based GAINS Processor is also connected as RT. The GAINS Processor is connected as Bus Controller (BC) to another Mil-1553-bus (G-bus) where a GPS Receiver is connected as RT.

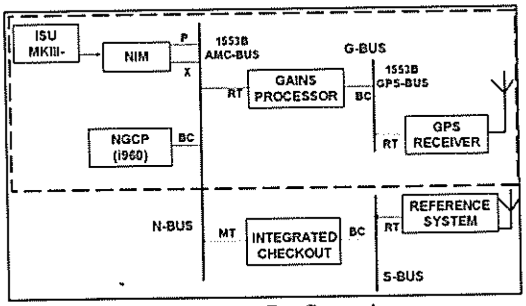



Fig [1]: Test Configuration

The integrated checkout system is connected to the N-bus and another bus called S-bus where the reference navigation system is connected as RT. The test setup includes the connections for the antenna for GPS and the reference system. Interfaces necessary for powering the packages, for monitoring and data acquisition are also needed, though not shown in fig [1].

The requirements to the checkout system included the functional requirements that deal with interacting with the test articles and special requirements related to the environment of use. These are categorized below:

*1. Functional Requirements*

These include the following:

- Powering and Interfacing with the test articles including ISU, NIM, NGCP, GAINS-Processor, GPS Receiver and the reference system.
- Continuous surveillance of the health of the test articles from the time they are powered on.
- Capability to acquire data from NIM, NGCP, GAINS-Processor and the reference system. This needs interfaces with two Mil-1553 buses.
- Implementation of test procedures with automation of intermediate steps.
- Capability to compare between three streams of data viz. Pure Inertial, GPS and Aided data.
- Capability to compare between data from GAINS and the reference system with the necessary conversions of time to obtain a common reference time.
- On-line display of critical parameters during the tests, from GAINS and the reference system.
- Implementation of procedures for Alignment and FR-Update tests. These procedures were specially designed for the aircraft tests.
- Need for tools for quick-look and detailed analysis of data. Automated tools were needed so that decision about the correctness of one test could be ascertained quickly to give clearance for the next sortie, so that multiple sorties could be conducted without putting off the packages.

*2. Special Requirements*

The special requirements are unique to this checkout system and pose major challenges to the designers. These include the following:

- Need to mount the checkout system along with the test articles securely on the Aircraft. A small aircraft is used, hence space is constrained.
- Need for rugged hardware to sustain the dynamics of flight. The hardware also must be of less size and weight.
- Power is to be obtained from the Aircraft Supply during sorties. An external source has to be used at other times. Provisions to easily switch between the external and aircraft power sources are needed in the checkout system.
- During sorties, continuous power to the test articles must be ensured.
- The sorties were of long duration at the rates of 45 minutes to one hour. Provisions must be available in the checkout system to support the long duration flight runs of the processors.
- An hour of the flight run would produce 76 MB of data. Checkout system should have the necessary capability to acquire and store data at these rates. After a sortie, the data must be made available for further analysis on ground. Periodic archival of data also is a requirement.
- In order to use the reference system, it is necessary to understand the new navigation system and its interfaces. The navigation parameters are posted with different periodicities.
- The schedule for the test is very tight, since an external agency (NRSA) is involved.
- The checkout system must be realized very quickly. The time available for checkout design is only a little over two months.

## III. DESIGN OF THE CHECKOUT SYSTEM

Some details of the design of the checkout system are explained here.

*1. Hardware Configuration*

The checkout hardware is realized using a single industrial PC mounted on a low-profile rack. Fig [2] shows the mechanical layout of the checkout systems and test articles inside the aircraft.

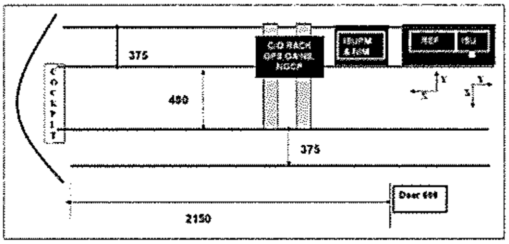
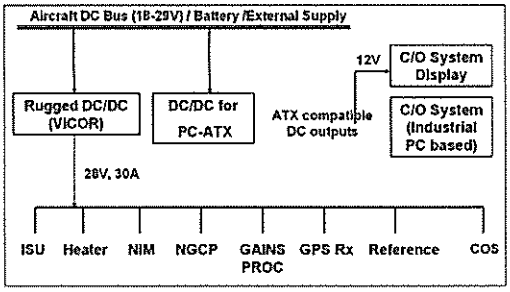



Fig [2]: Mechanical Layout

The features of the hardware include the following:

- A dedicated Signal Interface Adaptor (SIA) card is used to implement all the interfaces between checkout and test articles. These include the interfaces for powering, monitoring and data acquisition.

- The powering scheme is made in such a way that all systems are operated on 28V Aircraft supply. Fig[3] illustrates the powering scheme.




Fig[3]: Powering Scheme

- An intelligent, dual channel Mil-1553 Interface board is used for implementing the N-bus and S-bus interfaces.

2. *Software Configuration*

The software is designed to run on top of QNX real-time operating system and has the following features:

- The architecture is client-server. This is similar to the architecture of the existing RESINS Checkout system so that many of the design elements are reused.

- A set of cooperating and concurrent processes are designed to realize the functions of the checkout system. The processes include
  - **Checkout process:** which manages all the checkout operations.
  - **Telemetry process:** which enables the various real-time storage and display modules
  - **Reference System process:** used for commanding and monitoring the reference system
  - **Aided Display Client:** requests data from telemetry process and reference system process to provide a single integrated display for on-line decision making.
  - **Device drivers** for the various I/O devices like digital I/O, ADC and Mil-1553 cards.
- A Lap-Top based separate checkout system is used to interface with the reference navigation system in stand-alone mode. The variable data rate of reference navigation system is understood before it is integrated to main system. The capability to bring the reference navigation system from gyrocompass mode to navigation mode is tried out separately to exercise the on-line alignment option on RESINS system.
- A Lap-Top based mil-1553 monitoring system is designed as a stand-alone bus monitor. This system provides redundancy of data storage and is useful for diagnostic purposes.
- Data processing and analysis tools are designed for off-line data analysis of the test data from different sources. The comparison between GAINS and reference system is made easy by creating a set of script programs which made the time-line of both the systems in proper order.

## IV. DESIGN DECISIONS AND LESSONS

Some of the features in the design are examined in detail to illustrate the how the decisions made during the time of the design yield many returns.

*1. Powering Scheme*

It is decided to run all systems on 28: including PC, Monitor, the reference system and the test articles. A 28V, 40A DC-DC Power-Supply (VICOR) obtained from RCI, Hyderabad could be used. Use of devices that are readily available reduces the turn-around time.

*2. Design for continuous power*

A diode-OR'd scheme is implemented in power-input connecting the Aircraft Supply and an External power supply. This is done to handle aircraft power fluctuations during engine start. Aircraft power is expected to be the source of power for the entire tests once the checkout is loaded into the aircraft.

During the tests, it turns out that, aircraft supply is available only for a short period of time and sustains only a load of 25A. Hence the aircraft supply can only be made use of during the exact times of the sorties. The diode-ORed scheme makes it possible to use the external supply for ISU and Checkout until the start of sorties. A 230V AC in, 28V/40A Power Supply is used as the external supply. Moreover this scheme could withstand the dip in aircraft supply during engine start.

*3. Design for continuous power*

A by-pass control is designed for power input to RESINS using a manual switch and provisions in the software. This is required to maintain continuous power to packages during sorties and to prevent ISU going OFF due to any disturbance during flight. Relay commands are used to power the RESINS modules during normal operation. The manual over-ride capability ensures continuous power even if the relay trips due to some malfunction.

This provision proves useful while conducting transfer of flight data from the checkout system between sorties. Since the data was transferred to processing stations on ground, data collected for a sortie could be subjected to detailed analysis before the start of the next sortie itself. The provision for by-pass power is also used during short-term maintenance work on the checkout computer.

*4. Design of SIA*

It is needed to design and fabricate a small and rugged PCB, with all the necessary interfaces to realize the powering and monitoring requirements. The design of the PCB is made at IISU, and the layout made at VSSC. Fabrication is done with support from industry. The card is then wired and tested at IISU. The lesson learned here is to use all routes available when the schedule for realization is very short.

*5. Design of Software*

The design of software uses many mechanisms to shorten the turn-around time and to make the complexities of the system to within manageable limits. The techniques include the following:

- Definition of common data structures for transfer of data between processes for real-time display
- Use of existing data processing programs to process the data of the reference system. This is made possible by defining a new telemetry format for the data.
- Use of script programs for Quick-look data analysis. No additional software development is needed.
- Extending the capabilities of existing software modules used to implement the functions of powering, surveillance, flight-mode tests and initialization data preparation. The capabilities are extended to include all the different test articles.
- Independent processes are designed to realize specific functions. The processes communicate only through messages. Lack of coupling makes it possible to debug the system easily. The QNX message passing architecture becomes a handy choice.

## V. PROCESS OF IMPLEMENTATION

The checkout system is integrated with all the necessary interfaces at IISU. The packages are connected. Since the reference system is not available at IISU, a simulator of the reference system is made and used for validating the checkout system at IISU.

At NRSA, validation tests are conducted after connecting the reference system also. The checkout system and test articles are integrated and mounted aboard the aircraft, and a sequence of pre-flight tests conducted. A set of actions and the sequence of operations are identified for each of the sorties. Altogether, seven sorties were successfully completed and the entire flight data was archived.

## VI. CONCLUSION

The different steps in the design and implementation of a checkout system for the evaluation of GAINS under aircraft flight environment are highlighted. The tight schedule, environment of use and the complexity of functional requirements involving different navigation systems made this process a challenging one. On hindsight, the major factors that contributed to the successful culmination of this effort included detailed planning before execution, fast decision-making in the face of roadblocks in the realization route and modular design of the software. Teamwork between the three teams of IISU, NRSA and the aircraft pilots also contributed a great deal in this effort.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