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Under DARPA sponsorship, NOSC has made a dual contract award for advanced development brassboard models of a Global Positioning System Guidance Package (GGP). The approximate $28 million in contracts were awarded to the contractor teams of Texas Instruments and Honeywell and Litton Systems & Rockwell Collins. The existing 48 month (GGP Phase 1) contracts provide for the advanced development of a strapdown inertial guidance package comprised of a navigation grade Interferrometric Fiberoptic Gyro (IFOG) tightly coupled to a miniaturized GPS receiver (MGR). The GGP exploits the synergisms achieved by combining inertially sensed Inertial Measurement Unit (IMU) movement with externally sensed GPS reference signals. The goal is to produce a combined GPS/IMU navigation grade system which will be miniaturized for easy insertion into any host vehicle, and inexpensive for use by expendable vehicles (weapons and platforms). Follow-on Phase 2 contracts will develop preproduction prototype GGP units tailored for specific platforms.

The GGP effort aims to match the navigation performance of the conventional technologies but fit within an envelope of 10 pounds total weight, 20 watts of power, 100 cubic inches of volume, and a per unit cost of $15,000. The brassboard units being developed undear the current Phase 1 contracts will fit within an envelope of 20 pounds, 30 to 40 watts, and 300 cubic inches of volume. The GGP builds upon the integrated circuit technology from the existing DARPA mini GPS receiver program combined with the following: (a) solid state linear accelerometers and fiber optic rotation sensors (gyros) for three axes inertial sensing, and (b) a data processor and associated software to implement a Kalman filter to integrate the sensor outputs and provide the navigation solution as well as filtered velocity, acceleration, and orientation data needed by the host vehicle. Major cost reduction breakthroughs are offered by FOG sensors which employ integrated optic chips for light wave processing along with the polarization preserving fiber optic rotation sensing coil and a broadband optical source. GGP host vehicle insertion is also aided by its packing/customizing achieved through modularity of MGR, IMU, and navigation microprocessor subsystems. Modularity is achieved with standardization of (1) the Kalman filter architecture in the navigation processor and (2) data transfer points (ports) interfacing the MGR and IMU sensors to the navigation processors.

Dual award contracts were issued for GGP Phase 1 because each prime contractor offered a significantly different approach to solving the technical challenges associated with the GGP.

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An Introduction to the GPS Guidance Package (GGP)

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Biography

William C. Homer is currently working at the Naval Ocean Systems Center (NOSC) in San Diego, California. He is the Program Manager for the GPS Guidance Package (GGP) Program, that is sponsored by the Defense Advanced Research Projects Agency (DARPA).

Abstract

Under DARPA sponsorship, NOSC has made a dual contract award for advanced development brassboard models of a Global Positioning System Guidance Package (GGP). The approximate $28 million in contracts were awarded to the contractor teams of Texas Instruments & Honeywell and Litton Systems & Rockwell Collins. The existing 48 month (GGP Phase 1) contracts provide for the advanced development of a strapdown inertial guidance package comprised of a navigation grade Interferrometric Fiberoptic Gyro (IFOG) tightly coupled to a miniaturized GPS receiver (MGR). The GGP exploits the synergisms achieved by combining inertially sensed Inertial Measurement Unit (IMU) movement with externally sensed GPS reference signals. The goal is to produce a combined GPS/IMU navigation grade system which will be miniaturized for easy insertion into any host vehicle, and inexpensive for use by expendable vehicles (weapons and platforms). Follow-on Phase 2 contracts will develop preproduction prototype GGP units tailored for specific platforms.

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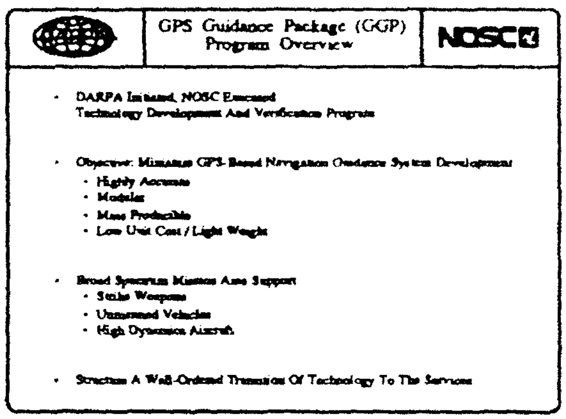
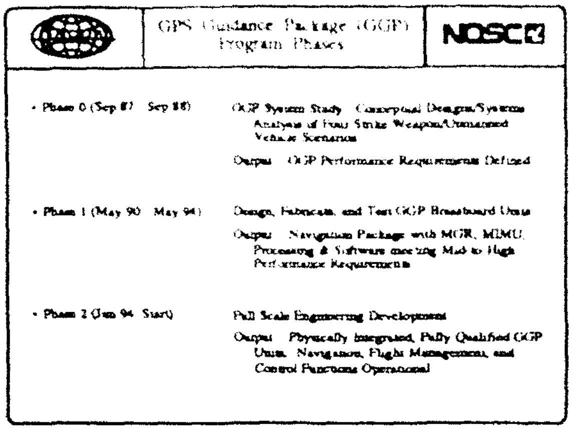
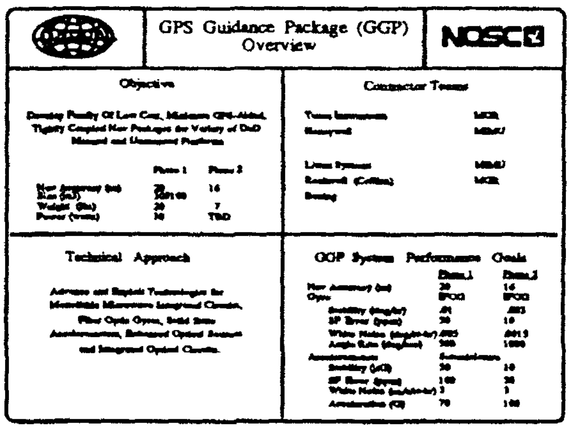
Introduction



DARPA initiated the GPS Guidance Package (GGP) program to develop a miniature guidance package based on a combination of a miniature GPS receiver (MGR), a miniature inertial measurement unit (MIMU), and control processors. The emphasis is on developing a small, low-cost, mass producible guidance package that will support a broad spectrum of Department of Defense (DoD) platforms including strike weapons, high dynamic aircraft, and unmanned vehicles. The GGP Program is divided into several developmental phases.



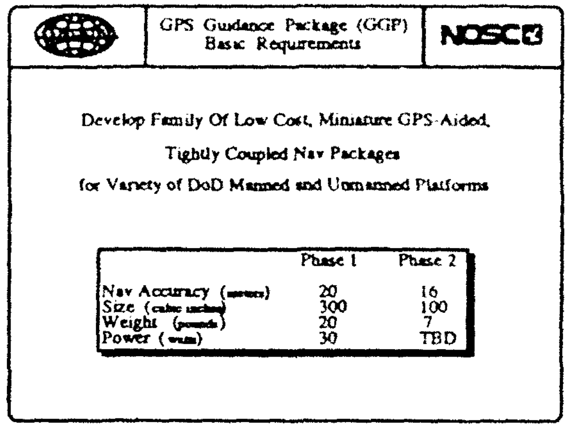
The objective of Phase 1 is to design, fabricate, and test a brassboard demonstration GGP unit consisting of a MGR, a MIMU, and the processors and software for a tightly-coupled integrated navigation package meeting the medium to upper level performance requirements established in Phase 0. Flight management and control are not part of the Phase 1 development model. The Full Scale Engineering Development phase, GGP Phase 2, will provide the miniaturized, fully qualified GGP units for rigorous operational testing and eventual installation into DoD platforms. Phase 1 is scheduled for completion in mid-calendar year 1994, with Phase 2 commencing shortly thereafter.



The GGP will perform a minimum of three functions: navigation, flight management (including guidance), and flight control. The navigation function provides high accuracy position, velocity, attitude, and time. Flight management contains the mission in the form of a trajectory to be used in the enroute phases of guidance and, using the navigation information, derives guidance commands to minimize the difference. The flight control function will accept the guidance commands and formulate commands to be applied to the vehicle control system. The navigation functions will be performed by the GGP, but flight management and flight control may be shared between the GGP and the host platform subsystems.

GGP Description

The Phase 1 GGP will meet the requirements of a brassboard demonstration navigation package employing a tightly coupled MGR and MIMU, based upon the use of advanced technologies suitable for miniaturization and capable of low cost in high volume production in subsequent phases of development. The Phase 2 GGP will have to demonstrate the established miniaturization, packaging, performance, and manufacturing goals prior to approval for large scale production.



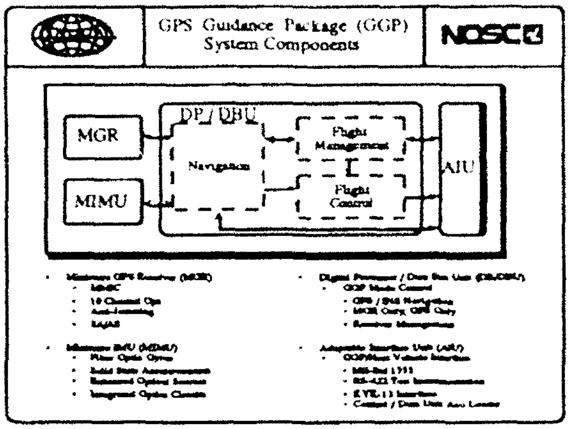
Performance Requirements

MGR positioning accuracy requirements will increase only slightly over existing capabilities, but significant advances must be achieved in the design and production of substantially smaller GPS receiver components. The most difficult challenge in the development of the GGP is the miniaturization and integration of the MIMU components into smaller and smaller packages with increasing accuracy and ruggedness requirements. The smaller volume and lower weight constraints should also expand the number of future vehicles for GGP use.

System Components

The GGP has four major components: the miniature GPS receiver (MGR), the miniature IMU (MIMU), the digital processor and data base unit (DB/DBU), and the adaptable interface unit (AIU). These components provide the primary navigational functions for the GGP with the following characteristics: (a) generation and maintenance of the estimated navigation solution by combining MGR and MIMU sensor data, (b) autonomous GPS or IMU operation when there is a fault in either the MGR or

MIMU, and (c) graceful performance degradation during navigation sensor outages. The MGR will



determine and track the optimal combination of GPS transmitters for maximum performance of the set. Using both P and C/A code, the multi-channel MGR is to provide ionospheric corrected pseudo range and delta range measurements; and complete selective availability and anti-spoofing (SA/AS) protection. The GGP is to accommodate multiple antennas and usage criteria based upon host vehicle attitude, signal quality, GPS transmitter selection, etc.

The MGR will be an integrated chip set consisting of *microwave monolithic integrated circuits* (MMICs) and application specific integrated circuits (ASICs) to implement the following: the RF/IF front end, analog-to-digital converter (ADC), frequency synthesizer, signal processor, and support/interface.

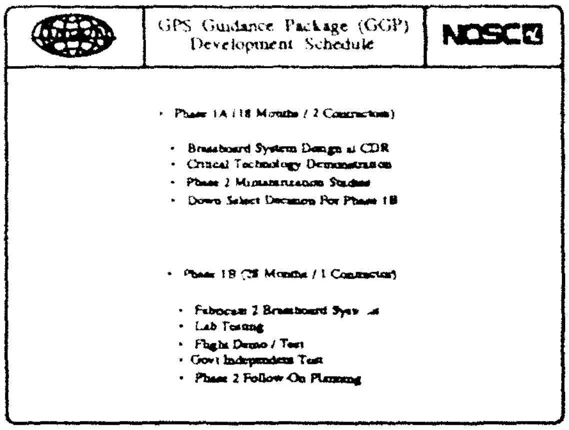
The MIMU will provide inertial acceleration and attitude rates (or delta velocity and delta angles) from sensed motion. It will also include the acceleration/attitude-rate sensors and associated electronics. The inertial rate sensors are to be of the interferometric fiber optic type and shall use a "long" wavelength (1.3 - 1.55 micron) optical source. The baseline accelerometers will be subminiature units of an advanced design or development based on a technology suitable for low cost volume production and emphasizing solid state techniques. However, currently available units meeting the GGP accelerometer requirements may be used to facilitate achievement of overall program objectives.

The DP/DBU will be based on either a federated or a distributed architecture for system control and initialization, integrated navigation, and MGR and MIMU control. For each DP/DBU processor, whether federated or distributed, at least 50 percent of the total memory and 50 percent of the total processing speed will be in reserve when operating at the required capacity. The design of the DP/DBU is to provide for an increase in memory and processing speed capacity such that with the addition of flight management and flight control functions in future phases, the same reserve requirements will be met. The DP/DBU will implement a tightly coupled integrated navigation solution using a single Kalman estimator, with synchronous interfaces to the MGR and the MIMU. Propagation of the solution using inertial measurements will provide "nominal" total state trajectory components and aiding data to the MGR. An extended Kalman filter shall estimate perturbation states, reset total states, and accept as measurements the residuals between MGR measured pseudo range and delta range in each MGR channel and corresponding quantities based on the propagated total state trajectory. The design of the Kalman filter and aiding of the MGR code/carrier tracking will deal with potentially destabilizing correlations between errors in the aiding signals and measurement errors, including the effects of a high jamming environment. An appropriate factorization will be used to implement the Kalman filter to enhance numerical stability and improve computational efficiency. The navigation processing architecture will be capable of incorporating other externally supplied position and/or velocity data (e.g. barometric altimeter altitude). The Kalman filter design for the integrated navigation configuration shall include, as a minimum, seventeen error states; and be subject to additional sensor error states where required to meet the navigational accuracy for a specific host vehicle or mission.

Design of the AIU is to be based on the future need to implement flight management and flight control functions, as well as the host vehicle and instrumentation interfaces needed for operation and test herein. As a minimum, the AIU shall provide a MIL-STD-1553 host vehicle interface, a RS422 test instrumentation interface, a control and display unit (CDU) interface, and a data loader interface. When the GGP is reconfigured by external command to perform the navigation function independent of the MIMU, the instrumentation interface will meet the standard instrumentation port and functionality requirements of ICD-GPS-215. A remote control and data unit will be provided for GGP control and display of data during the test and development phases. The data loader will be used in support of system initialization and startup.

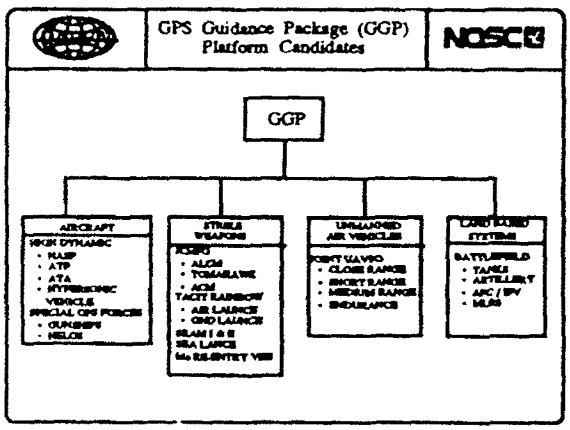
GGP Phase 1 Schedule

The GGP Program has completed the Preliminary Design Review stage and is enroute to Critical Design Reviews to occur near the end of calendar year 1991. The original contracts specified a "down-select" to a single contractor at the end of Phase 1A, for the development of the GGP brassboard prototypes. Recent and ongoing efforts to receive additional "non-DARPA" funding from possible GGP users are being conducted to preserve competition and provide GGP units on an advanced delivery schedule.



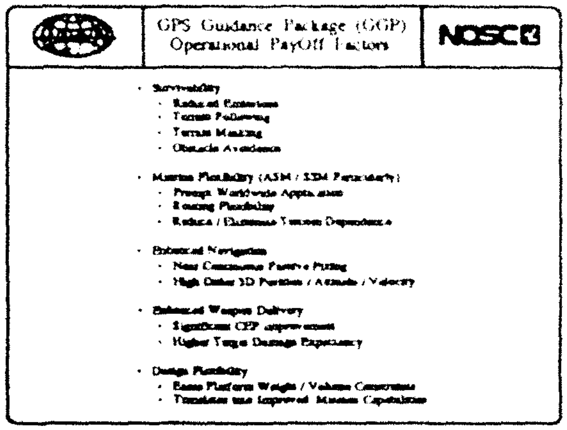
GGP Applications

The design goals for the GGP are to service the broad spectrum of DoD missions and platforms for the next few decades. As a "next generation" navigational aid, the GGP will internally incorporate the functions of existing GPS and IMU integrations. This will greatly simplify the installation and integration of this capability into operational platforms and unmanned vehicles. The entire families of autonomous strike weapons, unmanned vehicles, and other platforms with stringent space requirements stand to benefit from the successful development of the GGP.



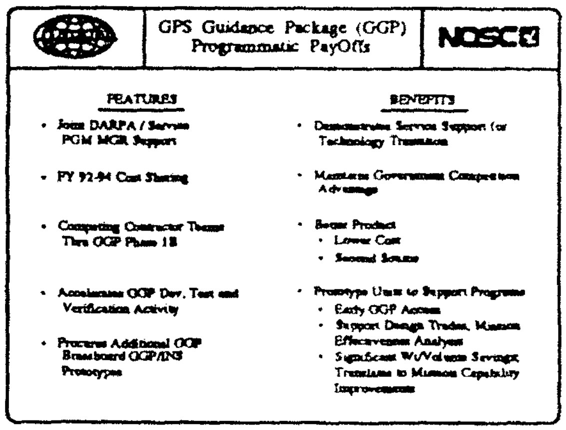
GGP Operational Payoffs

The receive-only nature of the GPS receiver, combined with the real-time positioning accuracies being demonstrated by today's receivers and integrated IMUs provide insight into the operational payoffs to be realized with the GGP. The long recognized benefits of the complimentary nature of IMU and GPS receiver measurements, when combined into a single small "black-box", overcome many of the existing constraints to todays arsenal of weaponry. The GGP will improve the survivability, increase the mission flexibility, and improve the delivery accuracy of weapons without increasing the vulnerability of the devices.



GGP Programmatic Payoffs

DARPA's continued development of mini-GPS components and miniaturized IMUs could provide the foundation for the infusion of "next generation" integrated navigational equipment for airborne and nautical DoD platforms. The transition of this new and innovative technology, along with the vast utility of its usage, is one of DARPA's primary goals for the GGP program.



The accelerated development of GGP units, through the cooperation and funding assistance from other DoD programs, can insure the rapid infusion of this much needed technology into future systems, which currently exist primarily in a conceptual stage.