Engineering Measurement System (EMS)

Project Charter

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PTCS Vision

The mission of the Precision Telescope Control System (PTCS) project is to collect and synthesize measurements related to the structure of the telescope, allowing for **more accurate monitoring** of the telescope structure and **improved control of telescope alignment and pointing**.

Traditional telescope control can allow the GBT to observe at low to medium observation frequencies. Beyond these frequencies structural uncertainties, gravitational, temperature and wind induced deformations and a variety of other effects render traditional means inadequate.

The ultimate goal of the PTCS is to
enable the telescope to perform at these higher frequencies.

Need for EMS

PTCS:

- At the top level, the PTCS consists of two main components:
- Precision Measurement System (PMS):
  - Uses metrology devices such as Laser Rangefinders and Quadrant Detector, together with other devices (inclinometers, accelerometers, etc) to precisely measure the location, orientation and shape of the optical elements of the GBT
- Precision Control System (PCS):
  - Uses the input demands and PMS measurements to control the optical elements of the GBT.

EMS:

- The optimal measurement strategies and data-processing algorithms for the PMS are not yet known.
- A key role of the EMS is to provide a prototyping environment to experiment with a variety of different measurement and processing strategies.
- The EMS will also provide a production platform with which engineering metrology measurements may be made, independently of the PTCS (e.g. surveying the antenna for structural integrity checks).

The EMS is a key component in the development path to the full PTCS!

EMS Vision

The goal of the **EMS** is to prototype processing data from the laser range finders to generate required information for PCS (or engineering applications) – in a routine and straightforward way.

This is a challenging problem for which significant R&D is required.

- STEP 1 → Implement tools to enable rapid algorithm development
- STEP 2 → Explore and develop algorithms and models
- STEP 3 → Implement a production-quality system to manage the collection and analysis of appropriate measurements on a regular basis

Step 1: Implement Tools

A Real-Time Rapid Prototyping Environment

PTCS engineers and scientists must have the means to easily investigate control methods and algorithms. They should be able to configure experiments and test these algorithms without the need to re-compile and re-install production quality software systems.

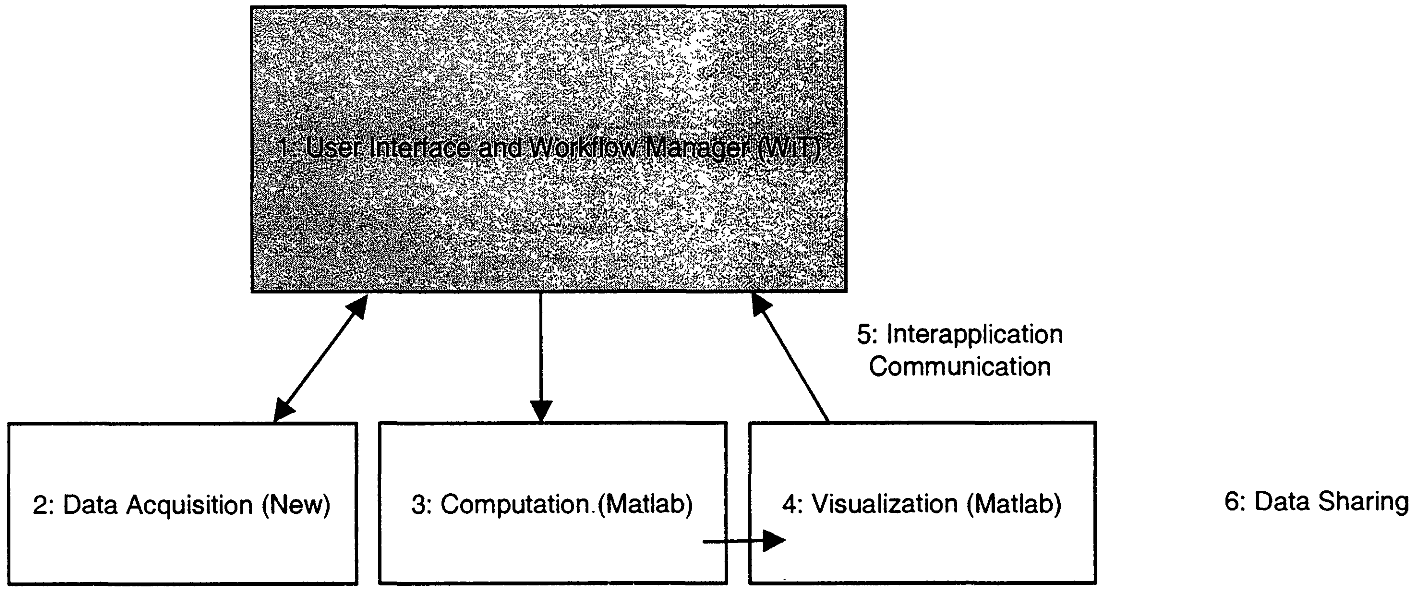
The **EMS Algorithm Development Platform (ADP)** will provide them with a real-time rapid prototyping environment that will allow them to:

- generate complex experiments
- test algorithms, and
- immediately view results

without the need for support from software (except to create and refine this environment).

Step 1 is primarily a software integration activity, with the goal of leveraging as much commercial off-the-shelf software as possible.

The EMS Algorithm Development Platform (ADP)



The complete platform integrates 6 capabilities to enable algorithm development, plus the ability for investigators to easily share results with one another for optimal time-to-convergence of algorithms.

<u>Note:</u> *Although the EMS ADP is being developed for PTCS, could be used as an algorithm development platform for other projects as well.*

WiT – for Workflow Management

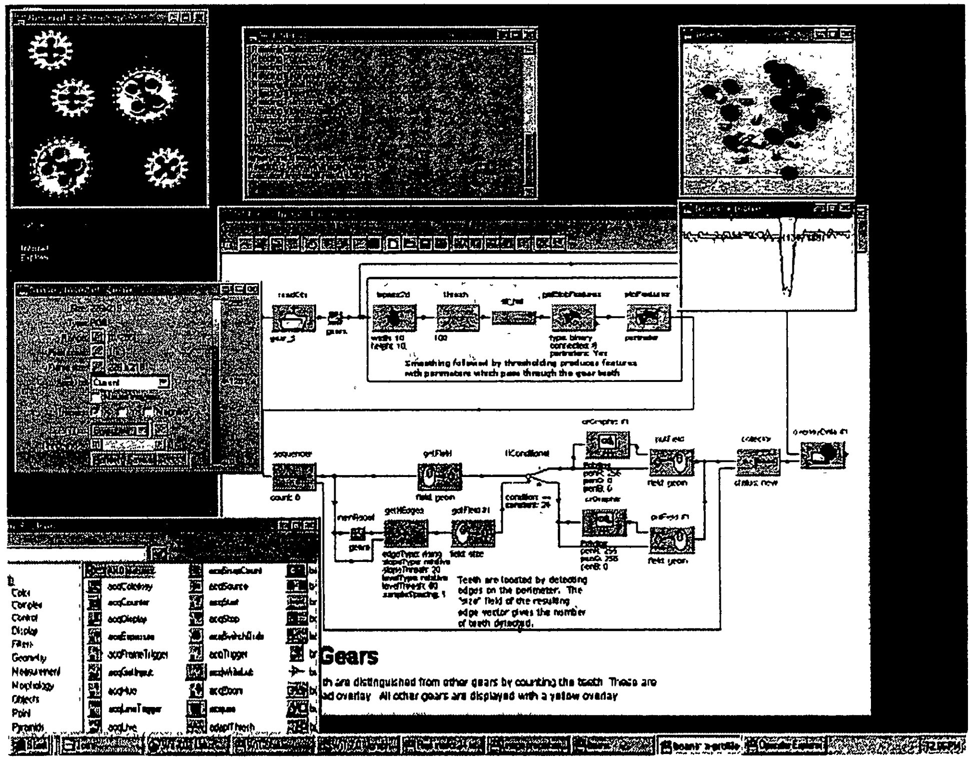
- WiT is a visual programming tool targeted to the image processing community.

- Algorithms are created by dragging and dropping icons that represent operations onto a workspace to create executable block diagrams called *igraphs*. Links between the icons direct data from one icon to the next.

- WiT provides a DLL interface to allow users to create custom operation icons.

- Signal Flow representation of a signal processing task.

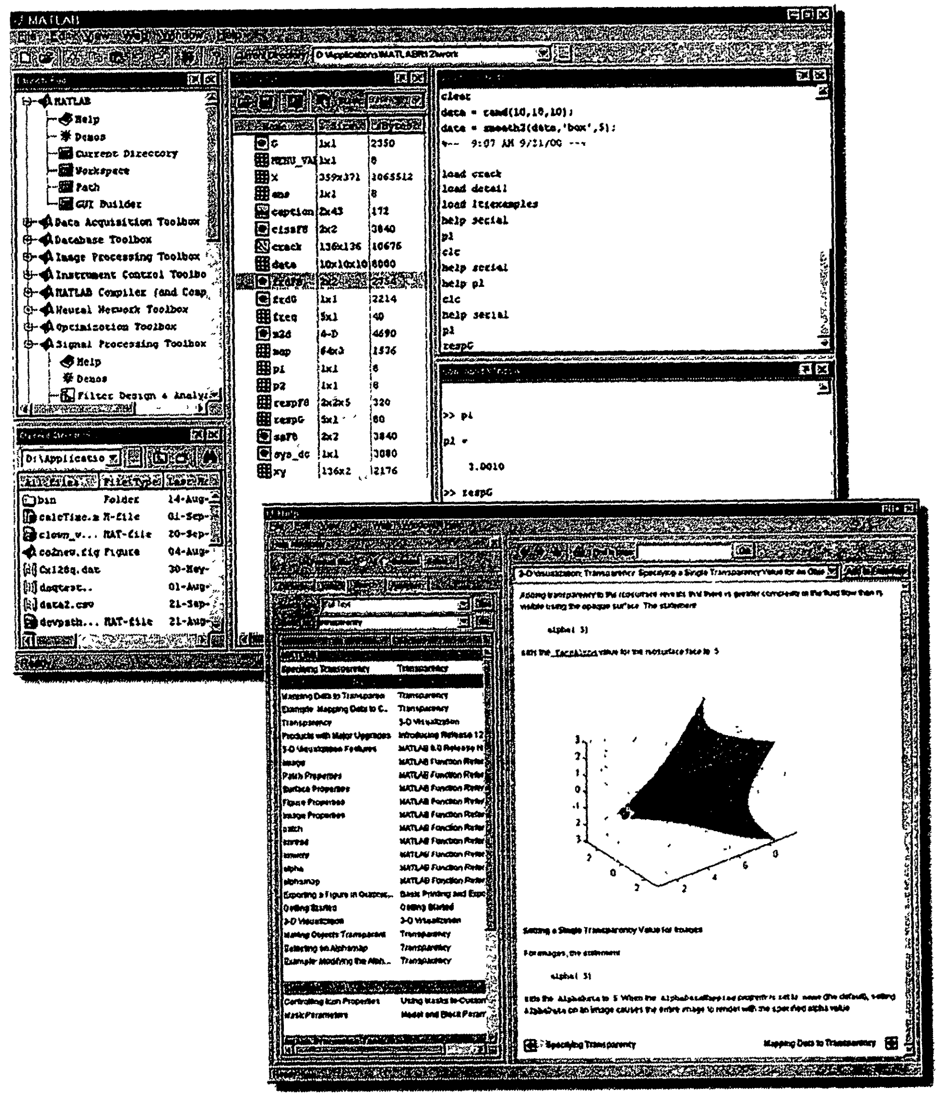
- Similar to Argonne National Laboratory's EPICS



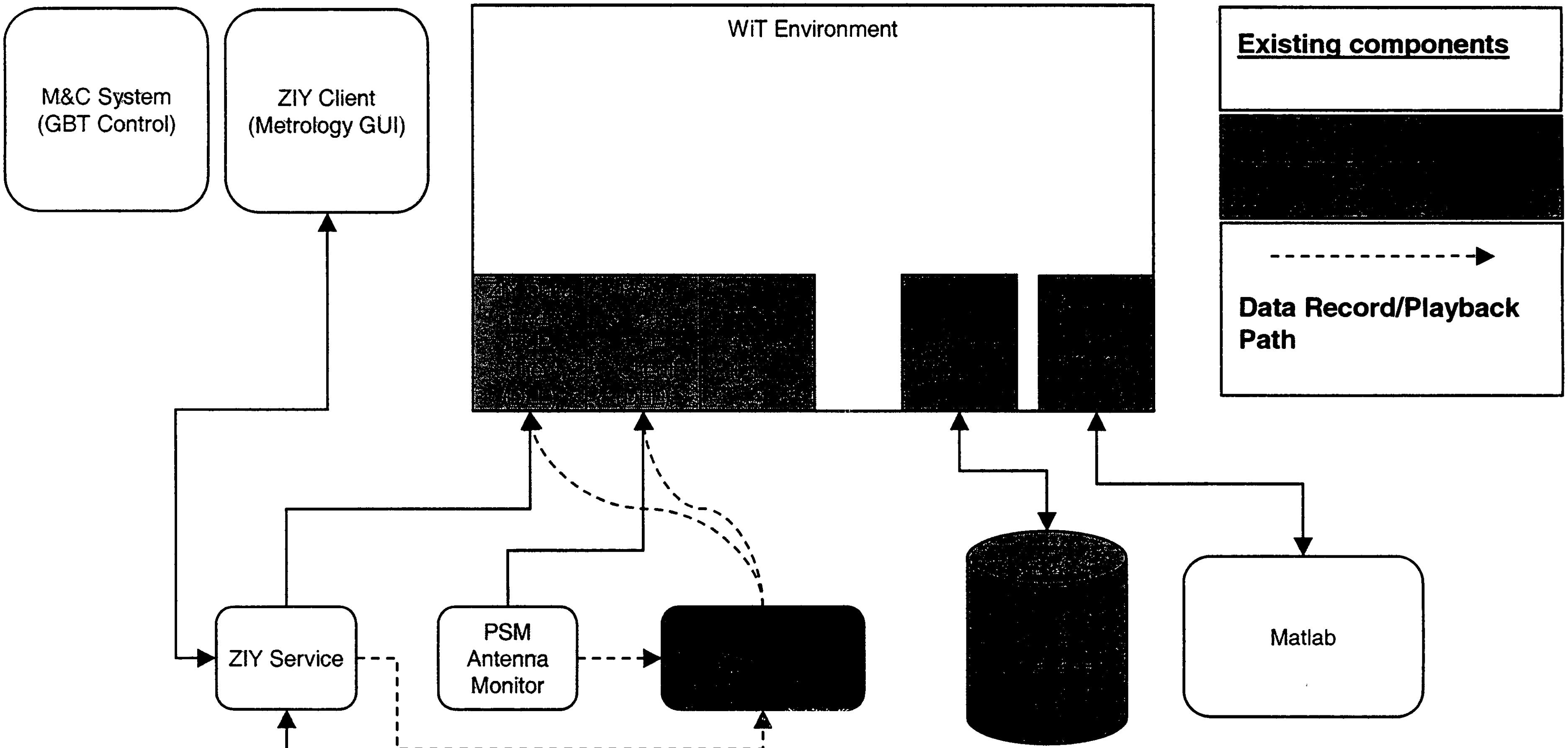
Matlab – for Computation and Visualization

- Matlab is a powerful, integrated mathematical computation and visualization tool. It is an ideal environment for developing and testing mathematical algorithms. Because of its open architecture, it lends itself readily to being integrated into EMS. Because of this, it can serve as the computing engine for EMS.

- Its key features are:
  - Numerical computation tools
  - Graphics for visualization and analysis of data
  - Interactive development
  - Interfaces to allow integration with other applications through COM, DDE & DLLs.



EMS ADP Application Architecture



Goal of the EMS Database is to preserve measurements in an easily accessible format to allow tracking over time:

- *Locations of various targets or points on the telescope within specified coordinate systems*
- *Calibrations associated with the laser range finders*
- *Characterizations and model output*

A Database Driven System

- To be developed from the existing gbt_metrology MySQL database, which already contains a large proportion of the data fields that will be necessary for the EMS
- Will provide a clear distinction between measured and inferred values

Components:

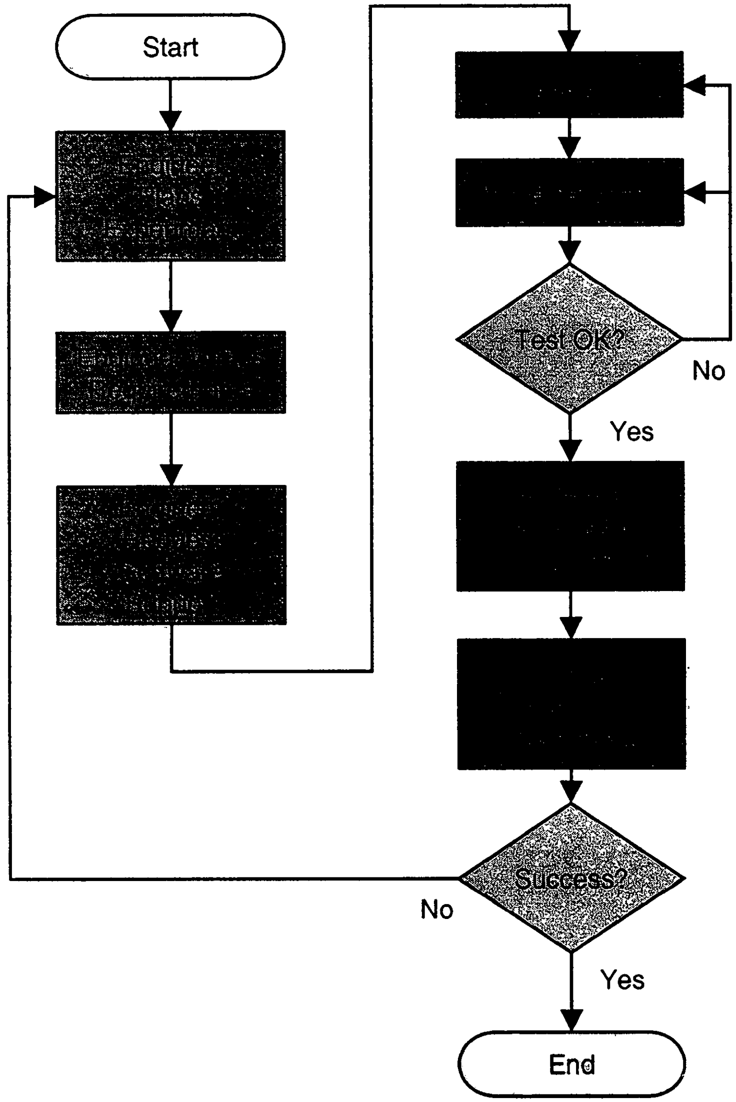
- **Measurements** – contains up-to-date knowledge about, but not limited to, the laser rangefinder system, including: calibrations on the laser rangefinders and piers, locations of and constants relating to the retros, and calibrations pertaining to the atmosphere
- **Experiments** – contains descriptions of experiments, application environment settings, experimentally determined data, and any other values needed to accurately and specifically characterize the experiment

EMS ADP User Scenario

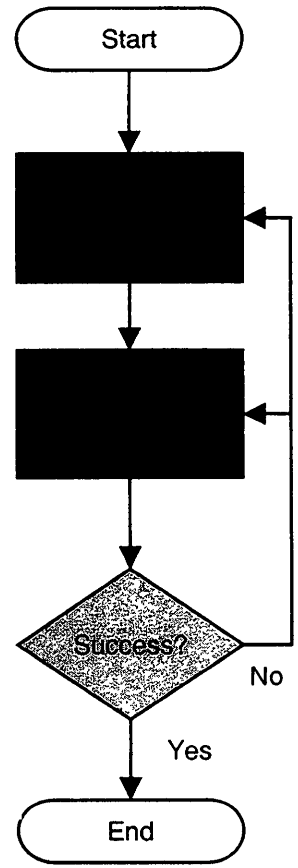
- EMS is conceived to allow the engineer unfettered access to the metrology system, and see immediate results.
- Can be used in real-time or off-line.
- When a PTCS scientist or engineer conceives of an experiment, he/she would use EMS something like this:
  1. If necessary, write algorithm(s) in Matlab
  2. If necessary, create the signal flow diagram in WiT, specifying the instruments and targets needed for the experiment
  3. Optionally, the engineer could test the experiment offline using old data and the playback capability of the `T.EXE` utility (`T.EXE` can read a file saved earlier and play it back displaced in time through a TCP server port, effectively mimicking the ZIY Service).
  4. Set up the Metrology system and the GBT using their respective user interfaces
  5. Run the experiment and check results. Using EMS, the engineer can then easily change the configuration or the algorithms and test again!

EMS ADP Enables Faster Algorithm Determination

A more traditional approach (2-3 months):



The EMS goal (1-2 days?)



Solution Components: Definitions

The following terms have been used throughout this solution strategy:

- **COM:** Component Object Model. The distributed object architecture used by Microsoft.
- **DLL:** Dynamic Link Library. A type of shared binary library used by the Win32 family of operating systems. These are the key components used in extending programs such as WiT and Matlab.
- **Matlab:** A mathematical & numerical computation and graphical display tool. Provides the EMS computation and visualization capabilities.
- **M&C System:** The GBT monitoring and control software system. The EMS will not control any hardware, thus M&C may be required to control some components needed by the EMS.
- **Metrology Interface:** The portion of the Metrology software system that provides a monitoring and control GUI for the operation of the system.
- **ODBC:** Open DataBase Connectivity. This is an Application Programming Interface (API) that allows a programmer to abstract a program from a database.
- **PTCS:** The Precision Telescope Control System. That subset of the M&C system that will be responsible for allowing the GBT to observe at frequencies higher that would be possible using traditional telescope control.
- **Trilateration:** The computation of a target's location given ranges from at least 3 ZY devices whose location is well known.
- **Visual C++:** The Microsoft C++ software development tool. Needed to develop DLLs for Matlab and WiT. These DLLs will act as the integration points between the two commercial applications.
- **WiT:** A graphical programming environment for rapid prototype development. Provides the environment that allows for the specification of workflow.
- **ZIY:** The Metrology System monitor and control software. Orchestrates the actions of the ZY units.
- **ZY (Laser Rangefinder):** The precision distance ranging instrument developed by NRAO.

In Scope

- Data Acquisition capabilities for the EMS ADP will initially be developed based on interfaces that currently exist to the GB M&C system and Metrology system.

- Implementation of the EMS ADP will be performed with full cognition of decisions made for the GBT Small Footprint Data Acquisition and Control Package (GDAQ), to be developed separately from the EMS. Additional interfaces may be developed to accommodate this.

- If the PTCS project team determines that incremental updates are required to the laser rangefinder system, these may also be performed in the context of EMS ADP development.

Out of Scope

- The EMS ADP will not control any hardware, but will simply provide a dashboard for the investigation of data provided by using other systems:
  - Laser Metrology hardware & software will be controlled from the Metrology System operator interface, ZIY Client
  - GBT will be controlled by operator through M&C/Cleo
  - Other PTCS metrology components (accelerometers, quadrant detector, etc.) will be accessed and controlled through M&C

- In initial implementation, EMS will not trilaterate on moving targets

Step 2: Explore Algorithms

Algorithm Exploration Will Include:

1. Trilateration using arbitrary retros, stationary telescope
2. Trilateration with moving telescope
3. Determining the position of a retro seen by any one or two laser rangefinders at a particular point in time
4. Fusing multiple measurements using optimal estimators (e.g. Kalman filters)
5. Sophisticated interpolation of signals
6. Extracting data that is regularly spaced in time from irregularly sampled data
7. Many more topics, to be determined dynamically throughout the R&D process

Step 3: Migrate to Production Systems

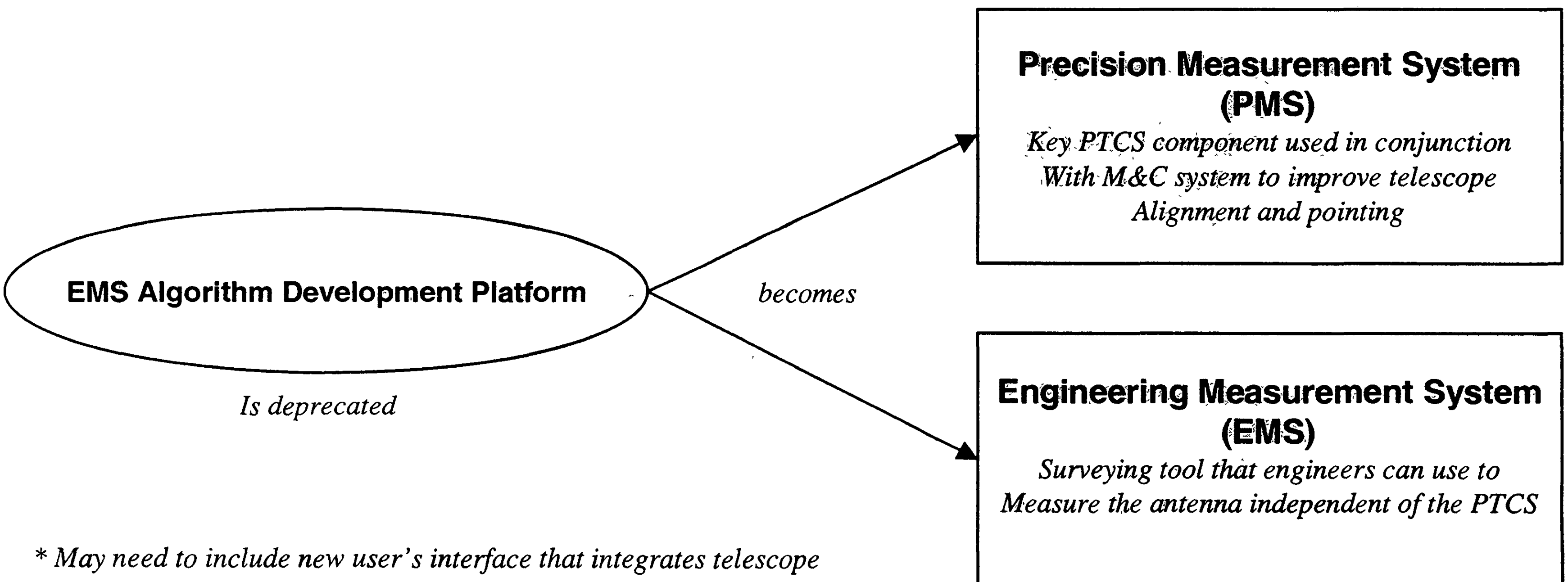
Migration Plan

Once the algorithms are determined, they will be

A) reimplemented in the GBT M&C framework for speed, reliability, robustness and compatibility reasons, or

B) the algorithm development platform will be evolved to become the PMS

Design details will be determined after the appropriate algorithms, and expected data rates through the system, are identified.



** May need to include new user's interface that integrates telescope control, metrology control, and the EMS/PMS.*

Project Planning

Task List

1	Complete EMS Charter	
2	1st release	This encompasses the bare minimum code to make EMS work (prototypes of all new components in application architecture, perhaps using existing Wells database)
3	1st Tests	Test the EMS infrastructure implemented in 1st release
4	1st Trilateration	This will be the first experiment run by a functional EMS
5	2nd release	Improvements to expand EMS capability. Includes: – transition to full featured database – trilateration of moving target – grid trilateration
6	Tutorial/Documentation	A simple and straightforward document to explain EMS basics