A network model control system (NMCS) for model and full scale tests

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Abstract: This paper describes the integrated model and full scale Control and Data Acquisition (NMCS) technology used in the model and full scale tests in the Ocean Coastal and River Engineering Portfolio of National Research Council of Canada.

The NMCS includes in a highly integrated suite of hardware and software all components required to:

- *Acquire real time data from multiple analog and digital instruments*
- *Store this data on digital media,*
- *Use the real-time data as inputs to real-time control functions, such as autopilots and Dynamic positioning components,*
- *Provide drive signals for multiple steering and propulsion elements, as well as other synchronized commands to devices such as winches, ballast systems, and roll compensation systems.*

The NMCS is based almost entirely on Commercial off the Shelf (COTS) components. These include;

- *Power sub-system components, power sources including batteries for free-running models and remote systems,*
- *Charging Systems,*
- *Power Safety interlock systems, E-Stop functions,*
- *Computers,*
- *Computer networking equipment all communications is handled via standard Ethernet devices.*
- *Motor Controllers and support components,*
- *Data Acquisition,*
- *Synchronization system, that coordinates, synchronizes all elements of acquisition and control,*
- *NRC written custom software provides integration for all of the various hardware functions.*

The underlying principle of the design was to integrate complex functions into a very flexible system that can be applied to any of NRC's model testing requirements, field trials with models or full scale trials systems.

The modularity of the system includes hardware and software aspects, that allow the experiment designer to tailor component content to their exact requirements, and makes it efficient to implement.

The core system design allows for the continuous addition of new functions, ongoing improvement of functions, as new requirements are defined or new technologies become available.

1. Why create the NMCS

The decision to design the Hardware/Software system that became the NMCS was driven by a desire to improve on quality, speed, and cost of delivery of advanced free running model testing solutions.

At NRC it was noted that as time passed, each test of a new model was becoming more and more sophisticated in the amount, number and quality of data to be collected and with steadily more advanced control methodologies. The challenge of accurately costing and scheduling the solutions for each new test requirement was becoming time consuming and the creation of a fully custom solution was while technically realisable, was neither cost effective nor robust enough for the testing environment. A decision was made to look at a new system that would have a standard set of hardware and software components and support the majority of our testing requirements. It was realised that for leading edge tests and those with very specialised requirements, custom solutions might still be required.

The baseline design requirement was to support the majority of our model tests with 'off-the-shelf' configurations for; Instrumentation and Data Acquisition of test parameters, and control of propulsion and steering elements. The method used to control of the propulsion and steering elements should allow both automatic control and manual control.

After a preliminary development of various alternate solutions, one based on Commercial-Off-The-Shelf (COTS) equipment was decided on. The technology available at the time coupled with the increasing amount of information / instrumentation being placed in models, as well as vastly increased data rates and the desire for high speed closed loop feedback control of model behaviour, demanded a communications method supporting high speed data transfer. Various communications technologies were examined, and standard Ethernet network equipment was chosen as the solution of choice.

The choice of standard Ethernet devices and software as the communications method between devices gave the system its name.

Other design choices included the use of an 'In-House' solution to the NMCS Software, the development of a custom power system and the transition to digital instruments wherever they meet our test specifications.

Details of the foundation components are covered in the next section.

2. NMCS Architecture

There are four base components to the NMCS. These components are a mix of hardware and interconnected software. First is the communications backbone, this is based on standard Ethernet technology, both hardware and software layers; second is the core NMCS software, including data acquisition, control and utility elements; Third is the Power System, including batteries, AC/DC power protection, distribution, and safety components; and fourth is the Support Component inventory, this includes all other devices that can be used to create a NCMCS application.

2.1 The Communications Backbone

The communications backbone supporting all data acquisition and control functions is based on standard Ethernet technology, the 'Network' of NMCS. All devices in any experimental arrangement must interface to standard Ethernet. The interface can be copper, fibre, or wireless at the physical layer. Various adaptors for electrical and protocol conversion are used to directly attach serial interface and other devices to the Ethernet. These include hardware based serial to Ethernet convertors, or software based approaches that allow serial devices to be plugged into a computer interface, and thus reach the Ethernet, and a Signal Conditioning/Analogue to Digital conversion system that is Ethernet based that covers the majority of analogue instruments.

Equipment includes both managed and un-managed Ethernet switches, wireless bridges, serial to Ethernet convertors, and many cables of various lengths.

The use of standard equipment, has due to the ever increasing capability of these systems, has allowed us to extend and expand the capabilities of the system on a continuous basis. The price of components has also decreased and their reliability increased greatly in the last five years.

2.2 Core Software

NMCS Software Suite: The overall function of any given arrangement of equipment is defined by a custom software suite developed at NRC. All devices are connected to Ethernet. The communications protocols are tailored to the attached devices function. The two major components of the software suite are the Data acquisition Sub-System, GDAC, and the motion control sub-system. The two elements are tied together with a set of custom software functions, which have a standard data exchange interface, allowing for the addition of new devices or functions.

The GDAC software suite covers all aspects of the data acquisition cycle from calibration to Quality Assurance products. Various components of GDAC are used to configure a given NMCS application before a test program. Once a test Program is underway there are elements which can be used to check functionality and quality of data offline, while the data acquisition core runs in the background. The Facility operator uses GDAC to control the acquisition of data during a test program.

The Control Software suite allows the use of both manual and automatic controls in any combination during a test program. The Control software suite Graphical User Interface (GUI) provides a front end that can be readily customized for each test configuration. It provides for the configuration of communications between all of the various computational and control elements on the network; The configuration, calibration and interface of manual and automatic control elements as well as various utilities that allow for custom pre-set manoeuvers to be programmed into the system prior to testing. Usually there is a model operator for the Control software suite GUI to operate the model during a test program, but the Facility operator can also have the GUI remoted to their work console, and thus control the entire test program.

Manual control elements include joy-sticks, wheels, thrust control elements, azipod controllers, etc. These elements/controls can be turned on or off and configured dynamically based on the test plan. Often a mix of manual and automatic is used in a single test element.

Automatic control elements available include; various Auto-Pilot implementations, Dynamic Positioning implementations, as well as specialized control axis such as anti-roll tanks and roll stabilization fin implementations. All of these elements are available as standard 'plug-ins'. It is possible to implement multiple automatic controllers in a single test, and integrate them with manual controls if required.

Extensions and customized elements are constantly being added to the system. New instruments, whether digital or analogue, are constantly being added to the NMCS via new software modules.

2.3 Power Systems

The power system philosophy at NRC has always been to separate 'Instrument' or 'clean power and Propulsion or 'Dirty' power. The NMCS has been designed around free running models, so the power supply system is battery based. A dual battery bank is incorporated into each deployment, the size depending on physical and operational requirements. Advanced lithium batteries have been used in all deployments of the NMCS. The majority of the batteries are still in service from the first batch originally used seven years ago.

2.4 Support Components

The current support devices include compact low power PC class computers and PLCs as the intelligent components. Ethernet based motor controllers and DC brushless servo motors to implement motion based systems, smart instruments with various digital interfaces, Ethernet based analogue data acquisition sub-systems, etc.

The addition of new hardware components has been simplified by the use of an interface standard. All instruments must be able to attach to the network. So selection of new instruments is a more focused activity, and as more devices have been added to the NMCS inventory proven hardware and software methods have been developed, thus reducing the time and cost involved.

3. Process for creating a NMCS application

Each NMCS application begins with a request for a model test proposal. As mentioned above the first step is to identify any non-standard requirements for Data or Control functions.
Basic Control and Data Acquisition System: Scale Model, Tow Tank Test.
In designing any given NMCS installation the process is the same.

The designer determines from the experimental design the number and type of motor axis, the number and type of instruments, and any special control functions required. A list of components, both hardware and software is assembled.

A network equipment diagram is then laid out and the devices required to implement the required instrumentation and control functions are added to the network equipment backbone diagram.

Addresses and component names are assigned according to an internal OCRE convention. A bonus side effect of standardized component use is that our documentation of each system has become both more complete and easier. After the first set of system documents were produced, cutting and pasting documentation element together from the original has allowed ready documentation of each new application.

The design is checked and verified by both the hardware and software groups.

The required software components are identified, and the level of effort of required customisation determined.

The required equipment is assembled from storage.

The assembly of the hardware usually takes place on the bench, the software is integrated as the hardware becomes functional, and bench integration, testing and commissioning takes place.

Once the model is manufactured, and the mechanical components are assembled into the model, an ordered assembly sequence takes place, components are added from the keel up in layers. Ballast volume provisions and mechanical components often dictate exactly where elements of the NMCS can be mounted.

Once assembly is complete, motor tuning in air with attached mechanical systems takes place, final calibrations are carried out, and the system is verified as functional.

The next step is to move the system to the tank; carryout final ballasting once deployed, and commence test preparations, and then carryout the test program.

4. Example System

A recent example of the NMCSs use is illustrated in the following paragraphs. The initial application was assembled for one model, but then was re-configured for the use in two other applications by adding and subtracting stock components.

Figure 1 shows the core components of a NMCS configuration prior to being placed in a model. In this case a fully submersible free running submarine. This same core unit was then used to control a model offshore supply vessel model, and an ice breaking freighter model. No changes, except the configuration of the software, the addition of more motor control axis, and changing battery capacity had to be made to allow the control core to operate these three very different vessels.

For the submarine implementation there was four axis of control, two sets of hydroplanes, a rudder, and the single propeller. There were three Batteries, and four motor controllers.

For the supply boat implementation there were nine axis of control. Five motor controller boxes were added to the configuration. Five additional batteries were also added to give greater capacity for more powerful motors and a longer planned test day.

For the Ice breaking freighter, the number of controlled axis was reduced back to four. The battery configuration remained the same.

The functionality changes were software configuration changes. The additional equipment was basic wiring and mechanical installation. The amount of time to create and implement to the point of testing of the three totally different model tests was less than a third of what a comparable set of custom installation would have required.

Fig. 1 – Implementation of NMCS for Free Running Submersible Model

5. Summary

The major advantages of the NMCS architecture include;

- Simplification of Design Process; early recognition of technically challenging elements. Reduction in cost of designing test systems.
- Simplification of Estimating and quotation development; Reduction in cost of estimate preparation, and more accurate estimates
- Better documentation of test designs.
- Standardized equipment means that fewer unique components are used in the system, allowing for cost effective stocking of spares.
- The standardized hardware and software simplifies the extension and addition of both hardware and software elements in a reliable and cost effective manner.

In summary the NMCS has proven time and time again that a standardized set of equipment with the ability to plug and play many diverse elements, both hardware and software, to create complex model test configurations has reduced our cost per test, increased the quality of testing, and allowed more tests to take place in a shorter period of time.