NATO Interoperability and Re-Use Study Overview and Discussion

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NIREUS Inception and Organization

The NATO Naval Armaments Group on Ship Design NG6 recognizes the potential of modeling and simulation (M&S) in ship design and wishes to harmonize investment in and development of ship virtual prototypes, allowing wider re-use and interoperability. In November 1997, NG6 established a Specialist Team on Simulation Based Design and Virtual Prototyping (ST-SBDVP). The purpose of the Team is to share information on the benefits, risks, and costs of instituting the technologies and processes of SBDVP applied to the acquisition of naval warships. This includes aspects in human factors and safety, product and process behavior, interoperability and re-use of software, and technology integration employing common infrastructures for integrated teams.

During the course of the Specialist Team's work, a second track was developed, namely, a multi-nation simulation interoperability study. This study would use as the application test-bed manned and unmanned aircraft landings on warships, focusing on helicopters and unmanned aerial vehicles (UAVs). This application was chosen because of the national interest in this military operation as expressed by every member nation, and because of the possibility of modeling and simulating this dangerous operation as part of a joint Allied exercise. The title of this interoperability study is NATO/PfP Interoperability and REUse Study, or NIREUS.

Considerations which led to selection of the NIREUS problem space included:

- Production of a test case for multi-nation Virtual Prototyping collaboration.
- The military importance both nationally and NATO-wide.
- Development of a generic model architecture (to allow flexible interchange of software and data for both national and NATO-wide use).
- Demonstration of interoperability and re-use.
- HLA use in an international federation for ship acquisition.
- Use of Commercial & Government software.
- Unsolved problems that could benefit from international collaboration.

The chosen multi-national test case concerns a virtual prototype for Vertical Take-Off and Landing (VTOL) air vehicles landing on ships, focusing mainly on UAVs but also addressing conventional manned helicopters. NIREUS is an experience-base study, which is actually constructing a working multi-national federation. The first NIREUS federation is scheduled for demonstration in September 2001.

The NIREUS effort involves twelve participating nations, and is overseen by a Study Executive Steering Group (SESG) comprised of national representatives. The actual work of constructing the NIREUS federation is conducted by four teams, each provided with specific responsibilities and tagged with an arbitrary color (blue, yellow, green, red). Each team has a designated country responsible for team leadership, with a second country as alternate. The colored teams report to the SESG via a conference of the team leaders and the NIREUS International Project Team Leader.

The conglomeration of NIREUS colored teams has come to be known as the "Rainbow Team". The Blue Team, led by Italy, is responsible for M&S associated with the ship itself. The Yellow Team, led by UK, is responsible for M&S associated with the air vehicle and air wakes. The Green Team, led by France, is responsible for ship-air vehicle systems interoperability issues, such as landing algorithms, tracking sensors, and air vehicle touch down/tie down analysis. The Red Team, led by Germany, is responsible for simulation interoperability issues, such as federation integration, visualisation, and coordination of the Federation Object Model (FOM). Overall systems engineering responsibility lies with the International Project Team Leader, appointed from the US with a UK deputy.

Conceptual Model

The current NIREUS Conceptual Information Flow Diagram is given in Figure 1. It provides a high level conceptual model for the military operation to be performed. The color coding roughly maps the functions into three general modeling areas: ship modeling (blue), air vehicle modeling (yellow), and landing system modeling (green). In the most general case each of the objects shown would be interactive at runtime (e.g., wind gusts could occur, the ship may maneuver).

The scope of the NIREUS 2001 Federation will be limited to the landing operation of an air vehicle on an (aft) landing zone of a surface ship. So, it will be assumed the Federation will initialize with the ship and air vehicle pre-positioned at some initial positions appropriate for landing approach. The "pilot" in the conceptual model may be defined as: human-in-the-loop, human behavior representation, helicopter autopilot algorithms, or UAV computer algorithms. However, the initial NIREUS Federation will implement a maritime UAV with an automatic landing system.

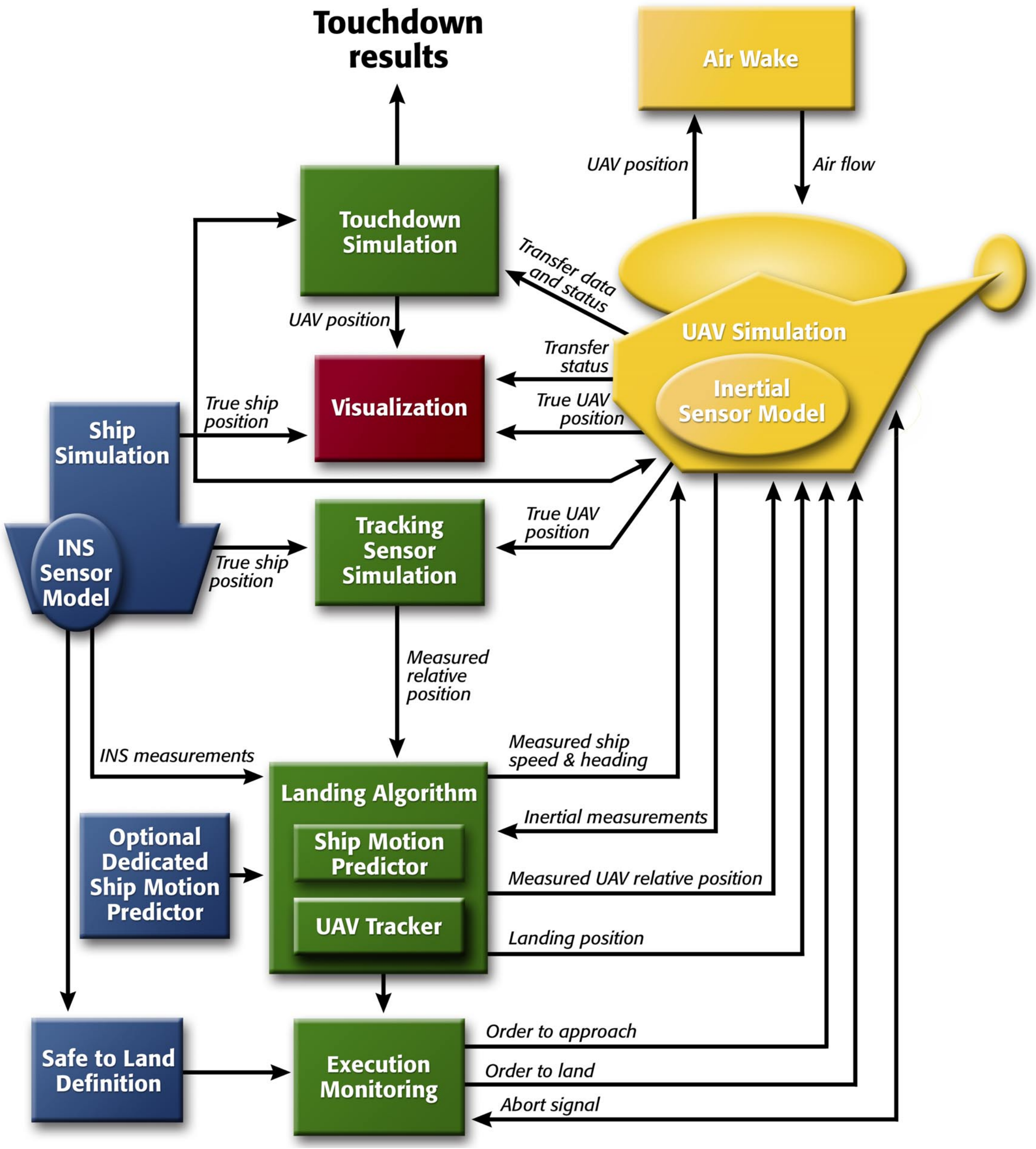

Figure 1 – NIREUS Conceptual Model

NIREUS 2001 Demonstration Federation

A total of six nations are writing software code for the 2001 NIREUS demonstration federation (see Figure 2). In addition, The Netherlands is writing support software (e.g., a test harness for stub testing federates prior to federation integration). Germany is leading overall federation integration.

Some federates consist of significant re-use of existing model codes (e.g., touch down dynamics), while some are primarily new codes (e.g., ship motion forward prediction). Similarly, some of the HLA interfacing code is being re-used from past efforts (e.g., ship motion), while others are newly written interfaces (tracking sensors). Also noteworthy is that five federates are in themselves multinational collaborations.

In the NIREUS federation design, three "blue" federates control ship information. The ship motion federate will publish data on ship position, ship hull motion, and landing zone motion. The ship motion federate will publish time history results from offline ship motion codes. The ship motion forward prediction federate uses measured (rather than true) ship motion data produced by the ship INS sensor federate. The ship motion forward prediction federate can produce two types of outputs. 'Mode 0' forward prediction data will look forward in time approximately 5-10 seconds to predict or designate a safe period in ship motion suitable for air vehicle landing. 'Mode 1' forward prediction data will look forward in time approximately 0.5 seconds to predict the exact position of the landing zone. This will be useful in descent path planning, by the air vehicle. In the NIREUS demonstration federation, Mode 1 data can also be provided by the landing algorithm federate.

A single air vehicle federate represents the air vehicle, with the "pilot" functions subsumed within. It represents the air vehicle's: motion, control systems, onboard sensors, and descent path planning. A separate air effects federate publishes the forces on the air vehicle resulting from prevailing winds, turbulence, ship air wake, and rotor downwash.

The "green" approach/landing algorithm federate synchronises the activities of the air vehicle, estimates relative air vehicle position, and helps to progress the scenario. The tracking sensors federate simulates sensor measurements of the position/orientation/motion of the air vehicle, relative to the ship. For the demonstration federation, the tracking sensor representation is simplistic, but could easily be replaced by a more complex model in the future. An abort condition may be declared by a combination of the air vehicle federate and the approach/landing algorithm. If the landing proceeds correctly, and a touch down is achieved, the touch down dynamics federate is invoked to examine the undercarriage impacts. The touch down dynamics federate will give the final indication of victory or defeat for the VTOL landing operation.

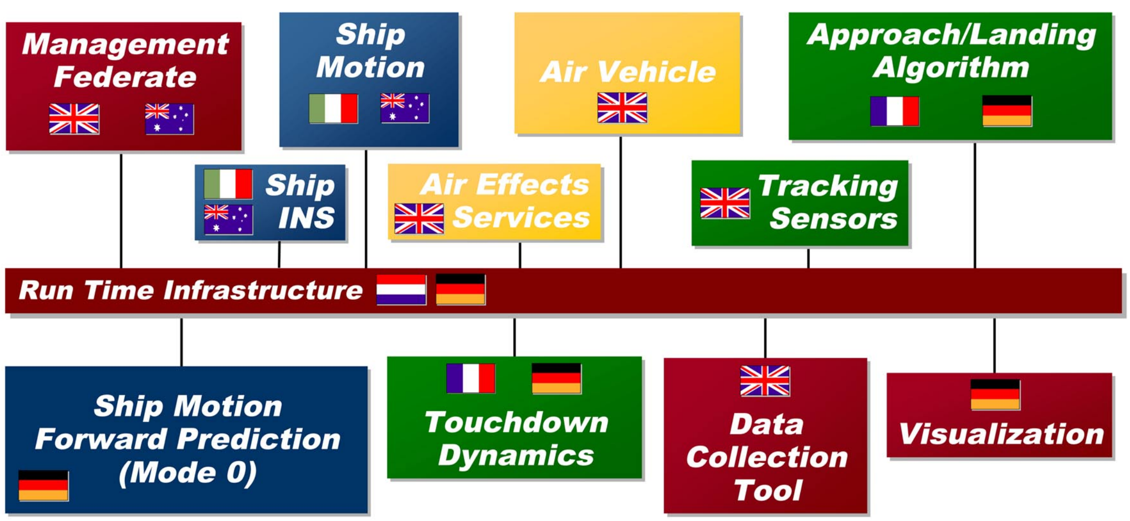

Figure 2 – NIREUS Federation Design

The NIREUS federation will be executed as a demonstration beginning in September 2001, first to the ST-SBDVP, then to NG-6 and others in the NATO hierarchy. The federation will be integrated on a LAN at a selected integration site in Toulon, France. It is hoped that integration at a single site will help mitigate the inevitable debugging that accompanies integration and initial federation execution. Further, the NIREUS red team has undertaken development of a test "harness" federation for local testing of individual federates prior to arrival at the integration site in Toulon. The test harness will provide a common set of stubs for the NIREUS federates, with which provide correct external RTI communications but minimal internal federate functionality.

Systems Engineering and Multi-National Collaboration

Simulation based acquisition draws awareness to the fact that the simulation of a system is itself a system. Fortunately, in IEEE 1516-compliant (HLA) distributed simulation, developers may avail themselves of the Federation Development and Execution Process (FEDEP). This is a systems engineering process that guides spiraled development of the simulation through phases of requirements, conceptual modeling, design, software development, integration, and execution. The NIREUS experiment has followed the FEDEP thus far, with excellent results.

Distributed simulations are as much a matter of engineering a system of people as of software. The cultural aspects of simulation-based acquisition are of high importance. Successful distributed simulation developments require partnership among various categories of players, presenting various cross-cultural divides:

- Executives and simulation sponsors
- Systems experts
    - Subdivided across various system types
- Simulation experts
    - Subdivided into system simulation experts and distributed simulation (HLA) experts.

NIREUS adds into this mix a further category:

- Multi-national membership.

The NIREUS experience thus far seems to indicate that at the working level, good balance between system experts and simulation experts leads to success. Leadership from both groups is important in successful construction of distributed simulations. NIREUS has evoked this balance by drawing some team leaders (blue/yellow/green) from technical systems experts in the respective areas, while in the meantime establishing a red team consisting primarily of simulation experts. Cross-team (ergo, cross-system) communication has been achieved through the establishment of the "rainbow" team, with the additional layer of a "team leaders conference". Unified communication with the NIREUS Study Executive Steering Group has been achieved through the establishment of a single International Project Team Leader.

The FEDEP is a process that is naturally founded upon negotiation. The HLA affords tremendous flexibility in federation design, where designers are not fed prescribed protocols for inter-simulation communication and simulation interoperability is not ostensibly technology-constrained. The FEDEP, particularly in the early steps, provides a framework to promote open negotiation of the federation design. It is important that the federation developers don't start to discuss networking of data bits until step 4 of the FEDEP – after the requirements, scenario, and conceptual model are agreed and documented. The creation of these critical early documents can be likened to negotiation of treaties among all the players listed above.

Further, designing and developing distributed, interoperable simulations is very much a discovery process. Communication across cultural categories tends to reveal both "unknowns" and overlaps. There always seem to be those things it's assumed somebody must be well-experienced in simulating, but actually no one is. A NIREUS example would be settling on the automated landing process controller, and more specifically the landing period predictor. Similarly, there are cross-system consistency and interdependency issues that are revealed. Natural environment representation always falls into the former, while (of course) coupled air wake effects fall into the latter.

Alternatively, great commonality across simulations is discovered. This can be in respect to different simulations of similar systems, or to similar components in simulations of different systems. A NIREUS example of the former would be ship motion representation. A NIREUS example of the latter would be sensor representations on ships vice air vehicles. Exploiting commonality can lead naturally to development of standards and easily re-usable software components.

Discovery of common strengths and needs has certainly helped promote multi-national partnership in NIREUS. Fortunately, following the FEDEP framework has been especially useful in fostering and focusing the necessary communication among the people. Moreso, the federation and team developments have commenced as synergistic concurrent activities. The FEDEP has enabled the team, and the team has enabled the FEDEP. Both are required to enable federation development. The NIREUS team has thus far found much success in the interplay of team development and simulation development, across a multi-national team.

Summary

The NIREUS study and its implementation as a HLA federation are scheduled for completion in September 2001. The twelve NATO Nations and Partners participating in this collaborative effort hope to advance the understanding of an important and dangerous military operation.

In the near term, NATO will reap the benefits of this multi-nation collaboration. Ultimately, the hope is that ship and aircraft designs can be improved by accounting for this operation, and that safe landing envelopes can be expanded, thus improving military effectiveness and safety.