UEI Application Notes:

FlightSafety uses UEI's RACKtangle™ I/O system

to dramatically improve the Sim*I/O* equipped flight simulators.

App Note #026

United Electronic Industries

Sim*I/O* — Application:

Abstract—There are a variety of factors that determine the viability of a new flight simulator. Chief among these are performance, uptime/availability, maintainability and ease of use. This paper will discuss how FlightSafety engineers, working in close conjunction with the UEI engineering team, have deployed UEI's "RACKtangle™" I/O series and made across the board improvements in the new Sim*I/O* equipped simulators

Introduction:

Piloting an aircraft without training is an inherently dangerous endeavor. Though early aviation pioneers were forced to take this risk or stay on the ground, this is no longer the case. Almost all pilots start their training in single engine, piston powered aircraft accompanied by a flight instructor. Most advanced training, and in particular, training of professional pilots in turbine powered aircraft, is now performed in a simulator.

Flight simulators offer a number of key advantages over training in actual aircraft. First and foremost is safety. It's possible to simulate almost any emergency or system failure in a simulator without risking life or limb. The same is certainly not true in an actual aircraft. It's perfectly safe for a student pilot to experience an engine failure on takeoff in a simulator. If the student is slow to abort the takeoff and the simulator runs off the runway, no damage is done (except to egos).

Another key advantage of flight simulator training is the cost savings of simulated flight versus actual. Though simulators are not inexpensive, it's still much less expensive for a pilot to take his/her "check ride" in a simulator than actually firing up and flying a Boeing, Airbus or other aircraft.

Though there were earlier attempts to build a ground based flight simulator, most consider the Link trainer developed by Edwin Link in 1929 to be the first "real" simulator. Following a number of US Army Air Corps accidents in the early 1930s, the army purchased four of Link's simulators and the flight simulator industry was born.

FlightSafety International was founded in 1951, dedicated to the principle that aviation safety is best achieved through training. With a fleet of nearly 400 simulators, FlightSafety is the world's leading supplier of flight simulators. Since the beginning, FlightSafety has been a leader in the developing simulator technology. For simulator training to be economically viable, simulators must:

1. Accurately replicate the "look and feel" of the actual aircraft
2. Provide an extraordinary level of reliability as most simulators are "flown" around the clock and are scheduled out weeks, if not months, in advance.
3. Allow quick repair. Simulators are complex devices and all devices can fail. It is critical to be able to diagnose and repair any failures quickly.
4. Be maintainable. A simulator is an expensive piece of capital equipment. To justify the investment, the simulator must have a long life, and so, must be assembled from components that will be available for many years.
5. Use standardized, well established components so new simulators, and in particular, simulators of new aircraft are developed in a timely manner with a minimum of new "learning curves" to be climbed.
6. Offer attractive pricing. Simulation is a competitive market. In order to prosper, a simulator must be able to offer competitive prices.

FlightSafety's new Sim*I/O* series simulators have been developed to meet all of the above requirements and more. Though FlightSafety's current simulators are the highest performance, most technologically advanced simulators available, the Sim*I/O* equipped simulators serve to further distance FlightSafety from the competition.

In their development of the new series, FlightSafety investigated a host of different I/O vendors and systems. In the end, the company has standardized all computer based I/O on the United Electronic Industries (UEI) RACKtangle I/O chassis and its associated I/O boards.

The remainder of this paper will detail how UEI's RACKtangle chassis is leveraged to achieve these goals in the new Sim*I/O* series simulators. We will break the discussion down into distinct advantages though you will notice there is frequently an overlap where a particular RACKtangle I/O chassis feature has a positive influence on more than one system issue.

High performance:

Performance is always an issue on a simulator. Obviously the goal is to make the simulator perform EXACTLY like the real aircraft. The new RACKtangle I/O equipped simulators have helped FlightSafety enhance the performance of the Sim*I/O* series in a number of ways.

1. The RACKTangle to computer interface is implemented via 1000base-T, Gigabit Ethernet. The Gigabit implementation ensures communications between inputs, the controlling computer and control/display output is fast and does not become a gating issue. Also, the ability to address 12 I/O boards in a single rack, with a single IP address reduces the overhead required to "talk" to the I/O system. The 12-slot rack provides up to 300 analog input, 384 analog output, 696 digital I/O or 144 ARINC-429 channels. The high Gigabit data transfer rate, combined with the low overhead enables system scan/update rates of 2000 Hz. This enhances overall system "smoothness" and allows control algorithms to make smaller, more accurate changes and adjustments.
2. Ensuring there are no "hiccups" or uncommanded "bumps" in the simulator requires the use of a computer with an operating system offering deterministic timing. There is no time to stop the control system algorithms while a disk drive is written or a monitor updated. The Sim*I/O* series utilizes the Ardence RTX® – Real-time Extension for Control of Windows operating system. UEI's RACKtangle chassis includes complete support for the RTX real time operating system (RTOS) as well as most other popular RTOS including QNX, RT Linux, and RTAI Linux. Though many I/O manufacturers have ignored the Linux/RTOS market or relegated the support to unofficial user forums, UEI drivers are factory written and fully supported.
3. On Sim*I/O* equipped simulators, the I/O chassis are mounted directly on the simulator itself as opposed to previous designs where the actual I/O interfaces were mounted in racks external to the simulator. The on-board location of the Sim*I/O* allows shorter wiring lengths, which decreases noise pickup and increases the system's overall signal to noise ratio.

High reliability:

Whether the simulator is operated by an airline, a government agency, or a training division of FlightSafety, unscheduled simulator down time is a disaster. Not only does it reduce billable/usable hours, it creates schedule chaos. Most simulators are operated "round the clock" and it is extremely difficult, if not impossible, to "make up" time lost by a down Simulator. In particular, pilots of part 121 airlines have extremely tight schedules, and their training schedules are not flexible. A pilot who misses a check ride because the Sim is down is effectively grounded. This not only causes hardship for the pilot, but also the airline, which is then forced to allocate a reserve pilot as a replacement. FlightSafety's simulators offer a remarkable 99.6% availability. Assuming the simulator is scheduled out 24/7, this represents less than three hours of down time per month. Two key factors determine simulator availability. These are reliability (typically expressed as mean time between failures or MTBF) and repairability (often referred to as mean time to repair or MTTR). The new RACKtangle I/O solution enhances both MTBF and MTTR. We will discuss the reliability advancements here while repairability topics will be covered in the next section.

The new UEI based Sim*I/O* equipped simulators are designed to improve on FlightSafety's already extraordinary reliability. Here's how:

1. Historically, simulators have been installed in two "parts"; the actual simulator and the external control station. All I/O connections had to be wired directly from the sim to the control panel. In complex aircraft, this requires a wiring harness containing over one thousand wires. The fact that the simulators move in 6 degrees of motion greatly complicates this connection and requires the use of a "waterfall" wiring scheme. The high I/O density of the UEI RACKtangle I/O chassis has allowed FlightSafety to build the entire control station into the simulator itself. The waterfall wiring harness on a Sim*I/O* equipped simulator now contains little more than power and Ethernet connections. All I/O wiring is fixed in place. The elimination of thousands of moving wires greatly reduces the probability of a broken wire or connector causing a system failure.
2. Today's aircraft cockpits are filled with annunciator lights and indicators. Turn them on at the same time and the cockpit takes on the look of a Christmas tree. Though there is a movement toward the use of high reliability LED indicators, the bulk of the indicators in most aircraft remain incandescent bulbs. Incandescent bulbs left on (or off) are extremely reliable and will last for years. There are reports of a bulb installed at a Texas opera house that has been burning constantly since September or 1908! However, the thermal shock, and corresponding rapid expansion/contraction of bulb filaments as they are turned on/off dramatically reduces bulb life. The Guardian series digital output modules installed in the UEI RACKtangle provide a pulse width modulated (PWM) "soft-start" capability. The soft-start allows the bulb filament to be brought up to temperature (and brightness) gradually enough that thermal shock is greatly reduced, yet quickly enough that there is no noticeable impact on the display. This feature dramatically improves bulb life and reduces down time. (Note the PWM feature can be set to run at steady state duty cycles. This allows the digital outputs to also serve as a "virtual rheostat" and allows the outputs to offer a "dimmer" capability in addition to simply turning bulbs on or off.)

Sim*I/O* — Application:

Rapid diagnosis and repairs:

FlightSafety simulators are remarkably reliable. However, failures in a device as complex as a simulator are inevitable. A critical design goal of the Sim*I/O* equipped simulators is to reduce the mean time to repair once a system or component has failed. UEI's RACKtangle I/O chassis has enabled FlightSafety to reduce the amount of time required for the repair technician to diagnose problems. It has also enabled the technicians to make many repairs more quickly. Many failures are now diagnosed and repaired in the amount of time it takes the crew to grab a cup of coffee. In fact, many failures can be fully diagnosed while the sim is still running! Also, the simpler and faster repairs made possible by the new Sim*I/O* diagnostics allow the simulation operator to maintain a smaller, less technically advanced repair and maintenance staff. Here's how the RACKtangle I/O chassis helps accomplish these goals.

1. Each RACKtangle I/O chassis provides two Ethernet connections, at independent IP addresses. One of the IP addresses is used by the simulator host computers to read and write the I/O. The second is available as a diagnostics "snoop in" port and diagnostics software may be run while the simulator is actually operational. Many, if not most, simulator failures do not bring the simulator "down", but merely make certain procedures or functions unavailable. It is often possible for the instructor to move on to a different part of the training syllabus with a "failed" system on board. The ability to run diagnostics concurrently with actual training will make it possible for the repair technician to identify the cause of a failure, determine which component(s) need replacement, acquire the components from stock, and prepare to perform the repair without stopping the training. Of course it's unlikely the repair can be made while the Sim is operating. However, since the technician knows exactly what to replace, how to replace it, and has the items in hand before bringing the sim down, the repairs are often made in minutes, not hours.
2. All Sim*I/O* inputs are connected to an internal switch that allows the input to be disconnected from the live Sim*I/O* and connected to a predefined test signal. Similarly, all Sim*I/O* outputs can be independently monitored. The ability to fully test all I/O automatically dramatically simplifies and speeds up diagnosing any problems identified in the cockpit or via system generated error alarms. This capability also allows complete self-tests and identifies wiring and installation problems without requiring manual wiring and continuity testing. A key aspect of the self diagnostics is the ability for the RACKtangle's digital outputs to monitor their actual output voltage and current, while the digital inputs are able to monitor hi and low, but are able to actually measure the input voltage with 25 mV accuracy. This measurement capability makes it possible not only to detect failures, but also to note changes in system behavior that might be predictive of pending failures.
3. The new Ethernet based "diagnostic IP" system enables a standard wireless interface to the technician's remote, hand-held diagnostic unit. In addition to identifying the problem, the system also provides instant access to any required schematics, user manuals, and/or wiring diagrams.
4. The second diagnostic IP address also supports a Web browser interface allowing a senior technician or engineer to access the system remotely. They can then diagnose and correct any issues beyond the local technician's capability without requiring any travel or travel related down-time.
5. The modular nature of the RACKtangle, combined with the ability to replace

any I/O module in a matter of seconds, greatly reduces repair time. The RACKtangle chassis contains no active components. All I/O modules, the CPU/NIC module and power supply modules are all easily replaced. The new Sim*I/O* system is based upon a small number of standard COTS components, reducing the on-site requirement for spares as well as ensuring fast access to replacement components when necessary.

6. Not all Simulator features and functions are used in every training session. Sim*I/O*'s self test and diagnostic capabilities allow the system to self test between sessions. The engine fire, cabin depressurization, or alternator failure warning annunciators might be used infrequently, but must work when commanded. The self-test features allow these components to be automatically checked. Should a failure be noted, it is possible for the technician to correct the situation between sessions, during scheduled maintenance, or while another repair is made without causing any down-time and without impacting training efficacy.

Extended simulator life:

Though efficient and cost effective, there is no debate that a flight simulator is an expensive piece of capital equipment. As such, a purchaser/operator of a flight simulator needs to know the device will be viable far into the future. UEI's RACKtangle I/O series was the perfect choice as the basis for the I/O requirements in the new Sim*I/O* series. Here's why.

1. Previous versions of FlightSafety's flight simulators have been based upon VME technology. Though many vendors remain committed to supporting the VME bus, many others, and in particular those focusing on I/O products are moving on to other platforms (e.g. Ethernet, LXI, etc.). To ensure long term availability of the hardware required to build new simulators as well as to support those already in the field, it was necessary to switch to a more stable architecture. (Note: FlightSafety has taken the necessary steps to ensure there will not be any disruption in support for existing simulators. Also, if required, it will be possible to retrofit existing simulators with Sim*I/O* hardware.)

2. The Ethernet in its various formats is ubiquitous and has been supported in one form or another since 1980. The Gigabit Ethernet interface currently used in UEI's RACKtangle I/O system is becoming well established in the I/O control environment and will provide a stable communications protocol for many years to come.

3. UEI and FlightSafety are partners in the Sim*I/O* endeavor. Previous simulators have been based upon I/O systems provided by a large number of different vendors. Though FlightSafety's I/O purchases were significant, they have not always been large enough to justify a particular vendor's continued production

of a given component. This is particularly the case as more and more of the VME based components have been "EOL-end of lifed". The UEI/FlightSafety partnership ensures a continued supply of product, now and in the future.

4. UEI serves a large number of OEM customers who depend on the company to provide a long-tem, uninterrupted supply of measurement and control products. UEI's commitment is demonstrated daily by the company's willingness to continue supplying its OEM customers ISA bus boards developed almost 20 years ago. UEI product support has even gone so far as to clone and provide a stable source of I/O boards that have been discontinued by other vendors. UEI is a vendor committed to long term support of its products and its OEM customers.

Timely development of new simulators:

Previous simulators have been based on I/O supplied by a variety of vendors. Though this situation was workable, it was not optimal. It mandated developers to use multiple, often dramatically different, software and hardware form factors. In the new Sim*I/O* equipped simulators, all I/O hardware and software, including avionics instrument control (AIC), control loading and motion (CLM) and flight deck I/O (FDK) is based upon the UEI RACKtangle I/O series. Here's how the UEI RACKtangle helps FlightSafety get their new simulators up and running quickly.

1. In the new Sim*I/O* architecture, all I/O is based on the UEI RACKtangle I/O chassis. This chassis allows great flexibility as any of the 25+ available I/O modules may be installed in any of the rack's 12 I/O slots. The standard form factor and footprint allow FlightSafety to standardize on the I/O and control bay on each simulator and yet have an almost limitless ability to configure the I/O to match the particular aircraft. The RACKtangle provides unprecedented I/O density, including up to 300 analog input, 384 analog output, 144 ARINC-429 channels per rack.

2. The software interface to all of the I/O capability is provided in a single, straightforward API. This dramatically reduces the time required by the software developers to actually write the application programs. It provides portability so application code may be shared among different development groups. It dramatically simplifies software documentation and maintenance as all the I/O is based upon a single driver. Finally, when a driver software update is required, it is achieved by updating a single driver.

Lower cost:

Though performance, availability, and supportability are the key issues that drove FlightSafety to standardize on the UEI RACKtangle series, the UEI system also provides all of its advantages and reduces the cost of Sim*I/O* equipped systems relative to previous configurations. The UEI based system reduces overall cost in a number of ways.

1. The UEI RACKtangle I/O costs less than the previous VME based systems.
2. The advanced diagnostics provided in Sim*I/O* equipped simulators dramatically reduce debugging of a newly built simulator. This reduces the time and labor costs required to get a new simulator up and running.
3. Reduced cost of construction due to the reduction in waterfall wiring required. This offers dramatic cost savings both in "parts" cost and in assembly labor. This is of particular note as almost all simulators are built twice. Once at the factory to prove proper operation, and then again at the simulator's final location in an FlightSafety or customer training facility.
4. The actual size of "on-simulator" equipment cabinet is reduced by over 50%. This reduces the cost of the structure required to support the I/O system.
5. Common I/O and chassis components reduce the requirement for on-site spare products. The spares requirement is also reduced as all of the RACKtangle components used in Sim*I/O* equipped simulators are standard COTS products at UEI and there are no long delivery schedules that need to be considered when it comes to planning the stock of spare components.

About UEI:

Founded in 1990, UEI is a leader in the computer based data acquisition and control industry. Serving customers world-wide, UEI products based upon PCI, PXI, ISA and Ethernet interfaces offer unequaled performance as well as flexibility. We are committed to providing the highest quality hardware, software and services, enabling engineers and scientists to interface data-acquisition and control hardware to the real world. Through our state-of-the-art technologies we serve the needs of individual researchers and developers as well as OEMs.

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