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SCALABLE INTEGRATION MODEL FOR OBJECTIVE RESOURCE CAPABILITY EVALUATIONS (SIM-FORCE)

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ABSTRACT

The Scalable Integration Model for Objective Resource Capability Evaluations (SIM-FORCE) provides Air Force decision-makers with a tool to evaluate potential actions and analyze expected results. The model evaluates the impact of schedule changes or resource availability on mission completion. It is a desktop tool that will support a wide variety of critical day to day decisions facing unit level managers. The simulation engine is built using Arena®. The simulation models aircraft launch processes, system breaks or failures and the resources required to support the launch and repair of broke items. The processes modeled are similar to those used by most types of maintenance, regardless of the type of equipment being maintained, including aircraft, industrial presses, recreational vehicles and long haul trucks. The modeled maintenance process is designed to transition SIM-FORCE into a future generic tool that supports commercial as well as military maintenance applications.

1 INTRODUCTION

SIM-FORCE is a modeling tool capable of meeting military or commercial requirements for answers to cost and productivity questions. The basic simulation engine is developed in Arena® and will process a wide variety of input scenarios. The initial effort focused on an F-16 fighter squadron in the United States Air Force (USAF). During the entire development process, the team has maintained the vision of a common simulation engine for multiple uses. Expanding the model to support other types of aircraft is straightforward. Adapting the model to commercial applications is underway. We plan to expand SIM-FORCE to model an industrial press line by the end of 1999.

This paper addresses the modeling approach and data requirements for a fighter squadron. It highlights the degree of complexity and level of detail addressed by the common engine.

2 SIM-FORCE OBJECTIVE

The initial objective of SIM-FORCE is to provide the military wing commander with a decision support tool that will assist in evaluating the impact of resource availability on the Wing's mission performance. Modeled resources include aircraft, parts, personnel, equipment, vehicles, and monies. The Wing Commander must allocate these limited resources to maximize the number of aircraft in the Wing that are Fully Mission Capable (FMC) and available to accomplish assigned missions.

SIM-FORCE will provide resource utilization statistics based on a detailed flying schedule or a more general turn schedule or utilization (UTE) rate. It will also provide cost estimates for flying missions at different UTE rates.

Our design goal is to produce SIM-FORCE using the Arena® Pack & Go capability. The Pack & Go will allow the user to change input values to the simulation for their unique organization and conditions and to run the simulation through the Arena® Viewer, which does not require the purchase of a run-time license.

User input is via Visual Basic® screens and Excel spreadsheets implemented through the VBA provided with Arena®. Output is provided to the user via Excel® charts and/or text files. User familiarity with Excel® worksheets and changing values in the worksheet cells will be necessary to set up input data and will provide flexibility in tailoring output to specific user needs.

3 MODELING APPROACH

This section identifies how the Wing operations, system failures and resources are modeled in SIM-FORCE. The simulation models the processes relating to preparing an aircraft for flight, flying the mission, recording flying time against an aircraft and engine, maintaining the aircraft in a mission capable state and repairing broken aircraft and/or components. In general, the processes modeled are the actions performed by the maintenance staff.

3.1 SIM-FORCE Potential Scenarios

The following describe three possible scenarios SIM-FORCE can address. A typical scenario may be:

The Wing is executing its current mission with no known deployments. The Logistics Commander would like to know where the potential bottlenecks in operations might appear during the planned mission in order to avoid shortages and delays.

The simulation can answer questions such as:

- If I execute the mission based on current schedules of personnel and equipment, where and on what day will there be probable delays or shortages in resources?
- If I keep the resource level the same and change the schedule, where will my shortages in resources appear?

Another possible scenario is:

The Logistics Commander gets an advanced warning of a potential deployment. The Commander would like to know how many resources (personnel and equipment) are realistically required to support the deployment and the effect of the deployment on accomplishing his/her current mission in the present time period.

The simulation can answer questions such as:

- If I deploy a certain number of resources, how long will it take to complete my current mission with the remaining resources?
- Using the remaining resources, can changing the flight schedule still allow me to complete my current mission by my original target date?
- Based on the conditions at the deployment base and given a number of aircraft, deployment duration, and the deployment schedule, how many resources (crew chiefs, flight line maintainers, electrical power carts, etc.) will I need to send to support the deployed aircraft?

A third scenario could be:

It is June 1st and the Wing Commander needs to give Higher Headquarters information on how long the current money will last or how much more money is needed to complete the current fiscal period.

The simulation can answer questions such as:

- How long will my Operations and Maintenance (O&M) budget last flying at my current UTE rate with my present resources?
- How much more money will I need to continue to operate until the end of the quarter based upon the current UTE rate?
- Based upon the current budget, what should my UTE rate be for this quarter?

3.2 Modes of Operation

Peacetime is the normal mode of operation and involves all the processes being simulated in SIM-FORCE. The model supports deployment as a decrease in resources and an increase in activity for the peacetime operations. SIM-FORCE models just the deployment mission by entering the aircraft, flight schedules and the resource levels for the deployment base. The user can adjust resources and process times to deployment values.

In wartime, SIM-FORCE uses the same sequence of operations as peacetime but nonapplicable steps are assigned a task duration of zero. The primary differences between peacetime and wartime in SIM-FORCE are in the quantity of resources available, the frequency of flights, and the reduced frequency of maintenance. These differences are controlled in SIM-FORCE through user input of the flying schedule, maintenance schedule and the number of available resources (personnel, parts, equipment, munitions, and facilities).

3.3 Future Capabilities

Future plans to support inclusion of several additional wing processes or characteristics is under consideration. Specific areas include the following.

3.3.1 Air Expeditionary Force

Inclusion of the Air Expeditionary Force (AEF) concept, a wing with more than one type of aircraft assigned, will require modeling of composite wings.

SIM-FORCE simulates the wing operation with the aircraft and resources that the wing supplies to the air expeditionary force (AEF) package removed as a deployment. SIM-FORCE will also support simulation of the operation and maintenance needs of the new wing of multiple MDSs defined by the AEF package.

3.3.2 Facilities

This simulation will not model the movements of aircraft or resources (people, equipment, and vehicles) between facilities, since time for movement does not have a significant impact on the maintenance function. However, the resources needed at certain locations will be modeled.

SIM-FORCE will model the resources needed at a facility. For example, the hot pit requires a munitions load crew and a fuel loader. The fuel barn requires fuel specialists.

Inputs to SIM-FORCE include:

- Capacity of each facility.

3.3.3 Time Compliance Technical Order(TCTO)

The TCTO schedule will define a given date when a TCTO must be complete on every aircraft in the Wing. It will also include the estimated time to complete the TCTO. SIM-FORCE will define a time period that is used to determine if a TCTO should be performed when an aircraft is in Wing phase maintenance. If the TCTO is not done on all Wing aircraft before the TCTO completion date, the model will cease processing the flight schedule until a delay time has past that accounts for completing the TCTO on the remaining aircraft to be serviced.

When emergency TCTO's are modeled, they could be modeled as a separate loop that delay a certain amount of time and then takes all aircraft into maintenance for a time specified on the TCTO. The user could specify if he wants this option and how many times it occurs in a simulation.

3.3.4 Depot Maintenance Schedule

The depot maintenance schedule will be modeled as an input list of tail numbers and dates when they are scheduled to begin and end depot maintenance. If the depot maintenance begin date is reached in the simulation, the number of aircraft assigned will be decremented by one. The tail number will be marked as unavailable. If the depot maintenance end date is reached in the simulation, the number of aircraft will be increased by one and the tail number will be marked as available.

Inputs to SIM-FORCE will include:

- Indication by tail number of aircraft in depot maintenance.
- Depot input and exit dates.

3.4 Model Time

SIM-FORCE simulates wing operations for a user-specified number of days in each replication. If the user chooses to fly aircraft by a turn schedule or a UTE rate, the model simulates the number of days specified by the user. If the user chooses to fly aircraft by a detailed schedule, SIM-FORCE simulates the number of days in the schedule. It is expected that the usual time period will be from one week to three months.

3.5 Wing Components

The Wing uses aircraft and a large pool of different resources to accomplish the assigned mission. Each Wing has a standard set of resources authorized but the actual resources onhand vary and the capability they provide also varies.

3.5.1 Aircraft

The individual aircraft assigned to each unit are the Wing Commander's tools to perform assigned missions. SIM-FORCE tracks aircraft individually by tail number (either user supplied or generated internally). Flying hours and number of sorties flown are accumulated for each tail number. SIM-FORCE needs the input of the Mission Design Series (MDS) of the aircraft and the squadron to which it belongs in order to support the AEF concept.

Inputs to SIM-FORCE depend on whether a detailed schedule, turn schedule or UTE rate is used. Inputs include:

- The MDS of aircraft (e.g. F-15, F-16) that make up a Wing.
- The total number of CANN aircraft.
- Tail numbers of all aircraft in the Wing and their accumulated flying hours.

3.5.2 Parts

Each wing has an assigned supply warehouse to store authorized spare parts. Aircraft failures cause a repair action and usually the need to replace a part.

3.5.2.1 Repairables

SIM-FORCE models the repair side process as probabilities that systems and parts will break and probabilities that certain personnel, equipment, and parts are needed to repair broken systems and parts. Probabilities of failure, mean time to repair (MTTR), standard deviations, and part costs are required input to the model. If a part is broken, the model assumes that the part is either fixed or replaced from supply at a pre-determined cost and within a probability distribution value of time based on the part's mean time until available and standard deviation. The personnel and equipment required to fix the part are required inputs to SIM-FORCE. The time required to fix is determined from mean times to fix and standard deviations. Facilities required to fix the part are always assumed to be available. Parts are not tracked to a specific aircraft, since parts do not necessarily go back on the same plane from which they are removed.

The rationale for these assumptions is that the Wing will do whatever is necessary to keep the aircraft operational, so the maintenance staff will either repair or replace a part in the expected time frame. The only time parts become critical are when the part can not be fixed in time and there are none in supply.

Parts cost are assumed to remain the same through the duration of the simulation.

The part information needed by SIM-FORCE are cost and time to replace or repair for each high driver part.

Inputs to SIM-FORCE include:

- Probability of failure of each high driver part.
- Mean time until available for each high driver part.
- Cost of repair of each high driver part.
- Probability of need of personnel and equipment to fix the part.
- Mean time personnel and equipment needed for repair.

3.5.2.2 Engines

Aircraft engines are the single most expensive part and consequently have unique management support soncepts that must be modeled. While engines are in an aircraft, they are identified with that aircraft. Removing an engine from an aircraft (e.g. during engine TAC inspection) breaks the connection, since the engine may go back into a different aircraft. Flying hours, number of sorties, and TAC are accumulated by SIM-FORCE for each engine by serial number.

3.5.2.3 Consumables

The consumables with the most impact on costs are fuel and tires. SIM-FORCE assumes an unlimited supply of consumables and a constant cost per sortie for all consumables. All aircraft are assumed to have new tires at the beginning of the simulation. The model deducts two constant costs, fuel and other consumables, from O&M monies at the end of a sortie. The other consumable cost is primarily the cost of tires. Most consumables have little impact on the costs or the time of maintenance, so they are not critical resources that need to be modeled. Fuel and tires are modeled because they are in constant use and necessary to the flying of aircraft. Over a period of time, their cost can be significant. Fuel cost is assumed to remain the same through the duration of the simulation.

Inputs to SIM-FORCE include:

- The combined cost of fuel and other consumables per sortie.

3.5.3 Personnel

The personnel specifically modeled are crew chiefs, weapons load crews, fuel loaders, and specialists. These personnel are critical to the maintenance function. If any of these personnel are not available, aircraft do not fly. All other personnel are not modeled and are assumed to be always available. These personnel include flight line maintainers and phase teams. Air crews are also modeled but the required capacity is always assumed available.

Since specific personnel are not assigned to specific aircraft or tasks, each separate personnel category is modeled as a pool of resources. For example, there will be a pool of crew chiefs that is drawn from whenever a crew chief is needed. The available capacity during different time periods during a day is defined in a schedule for each resource pool.

Each of the personnel categories follows a defined capacity schedule. The schedule takes into account vacation and training. The model translates the input schedule to a capacity schedule with capacities assigned to specific time durations. SIM-FORCE simulates unscheduled absences such as sick leave and emergencies based on an average time off that are input to the model.

The cost of personnel is not modeled. Compensation for personnel generally does not come out of the O&M monies given to the Wing to support its mission.

Inputs to SIM-FORCE include:

- A work schedule for each of the modeled personnel categories (e.g. crew chiefs, technicians).
- Average time off due to illness, injury, and emergencies.

3.5.4 Support Equipment

The support equipment currently modeled are the –60 electrical power cart, the C10 air conditioning unit, the mule hydraulic test stand, AGE tractors, fuel trucks, and tow vehicles. Each equipment item is required at various process steps. Specific equipment can also be required to support repair of specific parts.

Each of the different types of equipment and vehicles follow a defined capacity schedule. The schedules for vehicles takes into account whether the vehicle or the driver is the most constraining resource. For example, if in the period between 11 a.m. and 1 p.m. three fuel trucks are available, but only one driver is available (the rest are eating lunch), the scheduled capacity for fuel trucks from 11 a.m. to 1 p.m. will be one. The constraining resource is usually the vehicle.

The equipment schedules also takes into account the maintenance being performed on the equipment or vehicle, so the capacity during maintenance periods is reduced. The personnel required for maintenance and repair of the equipment and vehicles are not modeled. SIM-FORCE simulates unscheduled repairs based on an exponential

(EXPO) probability distribution with a mean failure value that is input to the model.

Each type of equipment and vehicle has a Mean Time Between Failure (MTBF) and MTTR. The MTTR will be used for unscheduled repairs. Inputs to SIM-FORCE for each type of equipment or vehicle include:

- Maintenance schedule.
- MTBF.
- MTTR.

3.5.5 Weapons

Loading weapons is modeled as a process step with distribution processing times based on aircraft type and configuration for a sortie. SIM-FORCE assumes that all weapons that are loaded are consumed.

Inputs to SIM-FORCE are:

- Parameters for distributions used as process times in loading weapons.

3.5.6 Monies

As a starting point for the model, the remaining O&M dollars is calculated from the dollars allocated at the beginning of the quarter and the dollars spent to-date as input by the user. At the end of each sortie, the cost of consumables (fuel and tires) is subtracted from the remaining dollars. Whenever a part needs repair, the cost of the repair is subtracted from the remaining dollars.

Inputs to SIM-FORCE will include:

- Dollars allocated at beginning of period.
- Dollars spent to-date in period.

3.5.7 Schedule

The Wing mission is incrementally accomplished by the individual sorties on the flight schedule. The user may enter a detailed schedule to drive the simulation. A user-defined schedule requires some level of user competence in building schedules and understanding the input required by SIM-FORCE. The user-defined flight schedule as a minimum must include tail number, take-off time, land time, configuration indicator, a surge indicator, and a deployment indicator. If a flight schedule is input, it determines the number of sorties per day for a given aircraft.

Instead of defining a flight schedule, the user can choose to specify a turn schedule or UTE rate which is used by SIM-FORCE to determine the rate (i.e. schedule) at which to “fly” aircraft. The turn schedule or UTE rate based schedules follow the same logic as the user defined flight schedule and tracks data to specific aircraft.

A deployment mission has a unique identifier in the schedule that indicates the number of resources that are unavailable for a specified duration.

3.5.8 Maintenance Schedules

The Wing schedule includes a maintenance plan for performing scheduled maintenance on the aircraft and other support equipment. The most critical element in the maintenance schedule is the one for phase maintenance.

3.5.8.1 Wing Phase Maintenance Schedule

This simulation only models the formal Wing phase maintenance that is done on an aircraft after every 200 flying hours. If the aircraft’s accumulated flying hours are within a pre-determined number of hours of the 200 hour limit, the simulation marks the aircraft as unavailable for flying until phase maintenance is complete. Phase maintenance is modeled as a standard delay time.

Inputs to SIM-FORCE include:

- Indication by tail number of aircraft in phase maintenance.
- Phase duration.
- Hours remaining to phase by tail number.

3.5.8.2 TAC Inspections

Total Accrued Cycles (TAC) engine inspections, required at 3,000 and 6,000 cycles, are modeled in a similar fashion to phase maintenance. The simulation tracks TAC for each engine based on accrued flying hours and a factor for TAC/flying hour. If the engine’s TAC is within a pre-determined number of cycles of the 3000 or 6000 cycles, the simulation marks the engine as unavailable for use until the TAC inspection is complete. If a spare engine is not available, the aircraft is unavailable until a replacement engine becomes available.

3.5.8.3 Equipment Maintenance Schedules

The maintenance schedules for equipment and vehicles are modeled as adjustments to the resource availabilities in the capacity schedules for these resources. If a vehicle is scheduled for maintenance, then the vehicle resource availability is reduced by one during that time period.

3.6 Wing Operations

The process to fly aircraft sorties involves a series of planned steps. SIM_FORCE models each sequence step as a delay with a probability distribution for the delay time. The parameters of the distribution are user input and differ depending on the aircraft MDS, the configuration for the sortie and whether the aircraft is turning (flying another sortie in close proximity to the landing time). Some steps may not occur if the configuration or turn of an aircraft indicates a process time of 0 for that step. SIM-FORCE checks for 0 process time and if the process time is 0, does not try to "seize" required resources.

The model currently assumes that the resources required at each step do not change from Wing to Wing. In the generic model, the user is allowed to specify which resources are required at each step. So in the future, the resources required at each step may indeed vary between Wings.

3.6.1 Configure Aircraft

The configuration process is modeled as four separate steps: configuring the aircraft, loading weapons, fueling, and loading software. The configuration steps that are performed depends on the configuration of the aircraft that is specified in the flight schedule. The loading weapons step requires one weapons load team. The fueling step requires one crew chief and one fuel truck. The loading software step requires one avionics specialist.

3.6.2 Crew Chief Pre-flight

The crew chief pre-flight is modeled as a separate step. This step requires one crew chief.

3.6.3 Air Crew Pre-flight

The aircrew pre-flight is modeled as a separate step. This step requires one crew chief and one pilot.

3.6.4 Engine Start

Engine start, taxi, end of runway check, and take-off are not modeled as separate steps since they involve small percentages of the overall sequence time. Times for these steps are included in total aircrew pre-flight processing times. These four steps all require the crew chief and pilot that are already required for the aircrew preflight step.

3.6.5 Fly Mission

Flying the mission will be modeled as a separate step. When the user defines a detailed schedule, the process times will be based on the scheduled duration taken from the schedule. If the user specifies a turn schedule or UTE rate, the process times are based on discrete distributions of average sortie duration times. The Fly Mission step requires one pilot. Landing will not be modeled as a separate step since it involves a small percentage of the overall sequence time. Time for landing is included in Fly Mission processing times.

3.6.6 Debrief

Debrief is modeled as a separate step. This step requires one pilot and one avionics specialist.

3.6.7 Post Flight Inspection

Post Flight is modeled as a separate step. This step requires one crew chief.

3.6.8 Through Flight Inspection

Aircraft scheduled to fly more than once a day receive a through flight inspection between each flight. Through flight is similar to a pre-flight except the times are shorter and the probability for failure is reduced as fewer items on the aircraft are inspected. Through flight is simulated by the adjustment of process times for the Pre-flight and Post-flight Inspection steps.

3.6.9 Quick Turn

Quick turn is modeled by reading new process time parameters for the steps in the normal sequence and then executing the normal sequence steps. For any normal step that is not performed in a quick turn, the process time will be zero.

3.6.10 Fix Aircraft on Flight Line

At both the crew chief pre-flight and aircrew pre-flight steps, a failure probability determines if there is a system break in the aircraft. When a break occurs, probabilities of part breakage and probabilities of personnel and equipment need will determine when the aircraft will be fixed. If an aircraft cannot be fixed prior to 30 minutes before aircrew show, a spare aircraft replaces the broken one in the operation sequence. The personnel needed are based on the failed part and the type of personnel required to repair that system. The required equipment are part of the Wing equipment pool.

3.6.11 Repair Aircraft in Back Shops

Repairing parts in the back shops will be modeled as a delay time based on the MTTR of a part. A certain percentage of the time, the back shop will fix the part, the remaining percentage of time the part will be sent to a depot for repair. The part sent to the depot will be replaced by a part pulled from supply.

3.6.12 Deployment

Deployment is modeled as entries in the flight schedule that decrement resources (personnel and equipment) when aircraft are deployed and increment resources when aircraft return to the Wing.

4 MODEL INPUT

SIM-FORCE is being created with a Visual Basic® front end to permit the user to easily enter the necessary data to tailor the model parameters to his/her requirements. Default data values will be built into the Visual Basic® screens and Excel® spreadsheets for all user definable input. The user can make any changes required via Visual Basic® screens and their associated Excel® spreadsheets. Input data is entered into Arena® then programmatically converted to text files that can be read by Arena® READ modules.

In the first version of SIM-FORCE, some of the Excel® input will be defined by the developer based on current Wing data and will not be user-changeable. Future versions will allow editing and updating by the user.

The following is a list of example data input.

Simulation start and end dates (Day date – will assume start time 00:00 am if time not entered).

Aircraft MDS.

- Number of aircraft.
- Number of CANN aircraft.
- Number of aircraft in depot maintenance and phase maintenance.
- Aircraft tail numbers and accumulated flying hours.

Parameters for distributions used as process times in operation steps by MDS, configuration and turn.

Parts data file containing the following information for each "high driver" part.

- Reliability of each part.
- Cost of repairing each part.
- Time to repair each part.

Personnel Schedules – for each personnel category.

- Capacity and duration over the specified simulation period – schedule includes training and vacation.
- Average unscheduled time off.

Equipment Schedules – for each type equipment and vehicle.

- Capacity and duration over the specified simulation period (includes scheduled maintenance).
- MTBF.
- MTTR.

Monies.

- Dollars allocated at beginning of quarter.
- Dollars spent to-date.

Flying Schedule – over the specified simulation period (user definable on Excel spreadsheet).

- Aircraft tail number.
- Scheduled take-off time.
- Scheduled land time.
- Load - configuration (munitions and fuel).
- Turn indicator.

5 MODEL OUTPUT

SIM-FORCE output will be a combination of text files and Excel® tables and charts. The model output, shown below, includes the necessary information required to make critical, time sensitive decisions. Using our functional experience as a baseline and then using current USAF maintenance personnel, we will validate the output results to make sure they meet requirements.

- Resource utilization by resource by day.
- Resource utilization by resource overall.
- Average wait time for a resource by day.
- Number of times a resource is required vs. number of times available overall.
- Total average time delay between scheduled and actual take-offs.
- Total cost of parts and fuel.
- Total dollars spent or dollars remaining.
- Total sorties flown by day.

6 CONCLUSIONS

SIM_FORCE is a complex production model that enables managers in military aircraft and commercial industrial operations to assess the impact of changing resources and missions on their capacity and costs. It uses a standard simulation engine to conduct a wide variety of simulations with minor changes in the front-end data entry screens and the output format. SIM-FORCE will have many applications in government and commercial operations.

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