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# Mathematical Model of Sub-System Interactions for Forward Operating Bases

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## ABSTRACT

Operational and logistical inefficiencies, excessive resource demands and increased costs are some of the issues caused by poor initial planning of contingency base camps. In this paper, a method of modeling base camps is introduced using an object oriented approach to increase the flexibility in base camp design and operations. The Mathematical model begins with a system of equations that captures the relationships between various base camp subsystems and their respective inputs and outputs. Subsystems are objectified and their various inputs and outputs (fuel, power, water, waste, maintenance, etc.) are parameterized and solved for simultaneously each time there is a change in base camp design. The Dynamic architecture model facilitates the use of further dynamic design processes, such as automated generation of power distribution system for the base.

## Keywords
Forward operating base, contingency planning, dynamic design, system engineering

## 1. Introduction
Forward Operating Bases (FOB), or 'FOBs' are usually temporary military contingency base camps established to support and facilitate tactical operations on foreign soil. The term loosely applies to all temporary U.S. Central Command (CENTCOM) facilities on foreign ground, including but not limited to tactical bases, logistical supply bases, fire bases, patrol bases, and combat outposts [1]. FOBs are typically mission-specific, and vary widely in terms of function and structure depending on the size of the population supported, mission type and duration, types of military units supported, and the availability of local infrastructure. Population sizes of FOBs range from 50 to 20,000 depending on operational parameters.

Although attempts have recently been made to standardize FOBs, planning techniques and policies for building FOBs vary widely between camps. Manuals such as 'Redbook' and 'Sandbook' serve to create some guidelines for FOB planning; however, these resources are theatre specific, and do not contain adequate data regarding resource utilization, which is much-needed information for logistical planning. Very little data seems to have been collected regarding resource utilization for FOBs, leading to increased difficulty in base camp planning. This in turn creates inefficiency, waste, and longer lead times in deployment of essential facilities and force protection which may increase risk exposure to soldiers. Poor planning of FOBs can result in logistical difficulties, which may increase transportation time and expense, and increase risk exposure to convoys and support personnel.

A need exists for standardization and modularization in base camp planning in order to increase the efficiency and operational effectiveness of FOBs. Preliminary research efforts are being undertaken to methods of modeling and designing FOBs using an general approach so that they may be applied to various mission types. In this paper, a mathematical model for representing resource utilization requirements of FOBs is presented, and an example result for a battalion-sized FOB is provided. This model is able to predict the overall resource requirements of a given base camp based on its operational parameters and the predicted relationships between the subsystems of the FOB. This data may be used to better plan the facilities which the FOB will require to be more operationally effective, and the logistical support systems which will best serve it. Finally, the model may be incorporated into a larger base camp planning tool which is proposed for development in the future.

## 2. Background

A FOB is an "evolving military facility that supports the military operations of a deployed unit and provides necessary support and services for sustained operations [2]", with a particular focus on supporting expeditionary capabilities (the ability to deploy combined arms forces into any operational environment and operate effectively upon arrival) and campaign capabilities (the ability to sustain operations as long as necessary to conclude operations successfully) [2]. FOBs provide critical support for soldiers during tactical operations on foreign soil. At the height of recent operations, the total number of U.S. and coalition FOBs were approximately 400 in Afghanistan and 300 in Iraq [3]. Department of Defense expenditures on FOBs show how important FOBs are to U.S. peacekeeping efforts. The annual amount of money spent on construction of FOBs increased to $6.2b from $4.5b spent by the U.S. Army Corps of Engineers (USACE) between 2002 and 2008[3]. Table1 illustrates the types of FOBs which are built depending on duration, base type and population size.

Table 1[1]: FOB Types

| | | | | | |
|---|---|---|---|---|---|
| **By Duration** | | | | | |
| US Army Corps of Engineers | | | **Contingency** | | **Enduring** |
| | Organic <90 days | Initial <6 months | Temporary <24 months | Semi-permanent | Permanent |
| Army FM 3-34 | | Initial <6 months | Temporary 6-24 months | Semi-permanent 2-10 years | |
| USAREUR "Red Book" | | Initial <6 months | Temporary 6-24 months | Semi-permanent 2-25 years | |
| USCENTCOM "Sand Book" | | | **Contingency** | | **Permanent** |
| | Expeditionary | Initial | Temporary | | |
| **By Base Type** | Forward Operating Base | | Main Operations Base | | Enduring Base |
| **By Size** | Platoon-Company | | Battalion- Brigade | | Division |

A typical FOB (Refer Table 2) may contain some or all of the following facilities based on the mission supported: life support areas, toilet/shower facilities, logistical support facilities, dining facilities, postal facilities, laundry collection and distribution point, aviation facilities, communication and network center facilities, medical facilities, motor pool facilities, fuel storage facilities, waste collection facilities, ammunition supply points, training facilities, morale-welfare-recreation (MWR) facilities, mortuary facilities , fire protection , force protection, barber facilities, tailoring facilities and detention centers [4]. Other types of FOBs have variations of the above facilities in terms of equipment used and the number of people the facility can support.

The U.S. military is currently seeking methods to increase the effectiveness and efficiency of base camps, driven largely by the amounts of money being spent on fuel and water logistics for FOBs. Finding ways to reduce costs while maintaining operational effectiveness and flexibility are key Department of Defense (DOD) priorities. One key area of emphasis is finding ways to minimize the logistical footprint of FOBs by developing more effective resource allocation schemes. Finding ways to increase efficiency without reducing effectiveness of base camp operations will hopefully lead to reduced requirements for contractor support systems and personnel.

To apply a systems engineering approach with regard to improving FOB design it is necessary to understand how existing FOB subsystems interact and operate. Proper understanding of the complex interactions between base camp subsystems will make it possible to develop the models and algorithms required to find and eliminate sources of inefficiency currently found in FOBs. A systems engineering methodology will be applied across all three functional components of base camp development: planning/design, construction/deconstruction, and operations/management [5]. Advanced planning of resource utilization should not only result in reduced government expense but in lower risk exposure to personnel during logistical operations. This paper focuses on methods for improving the sustainability of FOBs by accurately estimating the quantities of resources required by a given FOB based on its operational parameters.

# 3. Methodology

## 3.1 Mathematical Model

An application of the systems engineering approach to designing base camps requires a thorough understanding of the sub-system interactions within a FOB. Proper understanding of the interactive behaviors involved in terms of resource utilization for a given facility set will assist planners in anticipating future needs in resources and equipment. Mathematical modeling of FOBs begins with identifying the various functional blocks or structures acquired from structural diagramming of FOB subsystems. Forty structure types were identified and mathematical relationships developed for these. This model was developed using an abstract modeling technique to represent the resource requirements for bases of various sizes. For the purposes of this example we will use a hypothetical base camp with a population required to support an operational battalion of 600 soldiers and the necessary support personnel to operate the base camp.

Each facility within the base camp is treated as an 'object,' with its own input and output parameters. These parameters are the resource requirements of the object and resources created by the object. The primary resources are:

1. Electricity (Watts): The total electricity that will be consumed/generated
2. Fuel (Gallons): The total fuel required
3. Potable Water (Gallons): Total potable water consumed across all facilities
4. Bottled Water (Gallons): Total bottled water consumed across all facilities
5. Storage area (Sq. ft.): Storage space used across all facilities
6. Personnel (Number): Number of support personnel required
7. Gray Waste Water (Gallons): Waste water (Gray) generated from all the facilities
8. Black Waste Water (Gallons): Waste water (Black) generated from all the facilities
9. Solid Waste (lbs.): Total solid waste generated from all the facilities
10. Food Service (lbs. of food/day): Food consumed per day
11. Footprint (Sq. ft.): Total footprint area
12. Maintenance (Hrs. per day): Total Maintenance hours for all the facilities

Many of the base camp facilities will be mission specific and user defined. However, other facilities will be variable depending on the overall needs of the base. For example, the base camp planner may decide that the base camp requires a kennel. A kennel is a mission-specific facility; however, it will generate demand for water, power, support staff, waste management, and other resources. This will have a discrete effect upon the number of dining facilities, power generators, latrines, and habitation facilities required for the base.

## 3.2 Equations Setup

Some of the individual consumption/generation numbers for the FOB facilities are taken from the Field manuals, although a significant amount of data was generated during the project with the cooperation of Department of Defense personnel. This was necessary to compensate for a general lack of available data. This data was generated using a combination of observations from United States Army Corps of Engineers personnel and the results of engineering estimations to provide realistic representations of base camp components.

From the data gathered and generated for the model, a system of approximately 500 linear equations was compiled to represent the resource inputs and outputs of all the facilities. With any incremental change in resource requirements, the system of equations is re-solved to compensate for the change. The Engineering Equation Solver™ (EES) [6], a commercial software package with an advanced integrated equation-set solver, is used to calculate the total estimated resource values for all facilities based on the interdependencies between facilities in the base camp. Table 2 shows the list of facilities that were taken into account when modeling a Battalion sized camp.

Equation (1) and Equation (2) are sums of the total electricity and diesel fuel consumed across all facilities inside the battalion sized FOB. Similar equations exist for potable water, bottled water, required storage area, support personnel, gray water and black water waste, solid waste, food service, total camp area, and maintenance hours required. The code snippet shown in Figure 1 shows how the array values are set up in EES for a Dining Facility.

Figure 2 shows the constants used in EES for calculating the total resource requirements for a battalion sized camp. A similar procedure is used to set up the array values for each of the remaining 39 facilities listed in Table 2.

Table 2: Facilities Modeled for Battalion size (600-1000 soldiers)

| | | | | |
|---|---|---|---|---|
| Dining Facilities | Parking Lot | Direct Exchange | Wastewater Treatment | Training Area |
| Laundry | Motor Pool | Barber | Solidwaste Treatment | Tailoring |
| Kennel | Ammunition Holding Area | Religious Services | Security Checkpoint1 | Mortuary |
| Latrines | Direct Support Maintenance | Electrical Generators | Security Checkpoint2 | Military Police |
| Showers | Fire Protection | Electrical Distribution | Tactical Operations Center | Bunkers |
| Medical | Supply Warehouse | Water Purification | Administrative Services | Airfield |
| Communication /Network Center | Postal facility | Water Storage | Morale Welfare center | Staging Areas |
| Housing | Roads | Water Distribution | Educational Services | Detention Areas |

ElectricityConsumedkW=
(DiningFacilities[1]+Laundry[1]+Kennel[1]+LatrinesAndShowers[1]+Medical[1]+Comm&NetworkCenter[1]+Housing[1]+AmmunitionHoldingArea[1]+DirectSupportMaintenance[1]+FireProtection[1]+ForceProtection[1]+SupplyWarehouse[1]+PostalFacility[1]+ParkingLot[1]+MotorPool[1]+Roads[1]+DirectExchange[1]+Barber[1]+ReligiousServices[1]+WaterPurification[1]+SolidWasteTreatment[1]+SecurityCheckpoint1[1]+SecurityCheckpoint2[1]+TacticalOperationsCenter[1]+Admin[1]+MWR[1]+Education[1]+TrainingArea[1]+Tailoring[1]+Mortuary[1]+MilitaryPolice[1]+Bunkers[1]+Airfield[1]+Staging[1]+DetentionArea[1])/1000 (1)

DieselFuel=
DiningFacilities[2]+Laundry[2]+Kennel[2]+LatrinesAndShowers[2]+Medical[2]+Comm&NetworkCenter[2]+Housing[2]+AmmunitionHoldingArea[2]+DirectSupportMaintenance[2]+FireProtection[2]+ForceProtection[2]+SupplyWarehouse[2]+PostalFacility[2]+ParkingLot[2]+MotorPool[2]+Roads[2]+DirectExchange[2]+Barber[2]+ReligiousServices[2]+ElectricalGeneration[2]+WaterPurification[2]+SolidWasteTreatment[2]+SecurityCheckpoint1[2]+SecurityCheckpoint2[2]+TacticalOperationsCenter[2]+Admin[2]+MWR[2]+Education[2]+TrainingArea[2]+Tailoring[2]+Mortuary[2]+MilitaryPolice[2]+Bunkers[2]+Staging[2]+DetentionArea[2]+Airfield[2] (2)

```
DiningFacilities[1] = 0.225*SoldierElectric*Personnel              "18% of per soldier electricity "
DiningFacilities[2] = 0.04*SoldierFuel*Personnel                   "4% "
DiningFacilities[3] =0.15*SoldierPotableWater*Personnel            "15%"
DiningFacilities[4] =0.6*SoldierBottledWater*Personnel             "60%"
DiningFacilities[5] =0.267*AverageStorageAreaofFacility*Personnel  "26.7%"
DiningFacilities[6] = 15                                           "15 per camp size"
DiningFacilities[7] = 0.06* SoldierGrayWater*Personnel             "6%"
DiningFacilities[8] = 0.08*SoldierBlackWater*Personnel             "8%"
DiningFacilities[9] = 0.3*SoldierSolidWaste*Personnel              "30%"
DiningFacilities[10] = 0.9*SoldierFood*Personnel                   "90%"
DiningFacilities[11] =0.07*SoldierFootPrint*Personnel              "7%"
DiningFacilities[12] = 0.235*SoldierMaintainence*Personnel         "23.5%"
```

Figure 1: Dining Facilities array numbers in EES

```
"Constants"

"Soldiers = 600"    "This is the number of soldiers being supported by the base camp"
"SoldierElectricforGenerate=3500"  "Power Available per soldier per day, in watts to be generated"
"SoldierElectric = 3000"  "Electrical Usage per soldier per day, in watts"
"SoldierFuel=5.5"  "Fuel Usage per soldier per day, in gallons"
"SoldierPotableWater=37.4"  "Potable water Usage per soldier per day, in gallons"
"SoldierBottledWater=2.8"  "Bottled water Usage per soldier per day, in gallons"
"AverageStorageAreaofFacility=7.2"  "Average Storage area of facility in terms of soldiers, in Sq.Ft"
"SoldierGrayWater=28.8"  "Gray water generated per soldier per day, in gallons"
"SoldierBlackWater=8.5"  "Black water generated per soldier per day, in gallons"
"SoldierSolidWaste=15.9"  "Solid waste generated per soldier per day, in pounds"
"SoldierFood=8.0"  "Food Consumed per soldier per day, in pounds"
"SoldierFootPrint=105.7"  "Average Foot print of facility in terms of soldiers, in Sq.Ft"
"SoldierMaintainence=0.3"  "Average Maintenance hrs per day, in Man hrs per day"
```

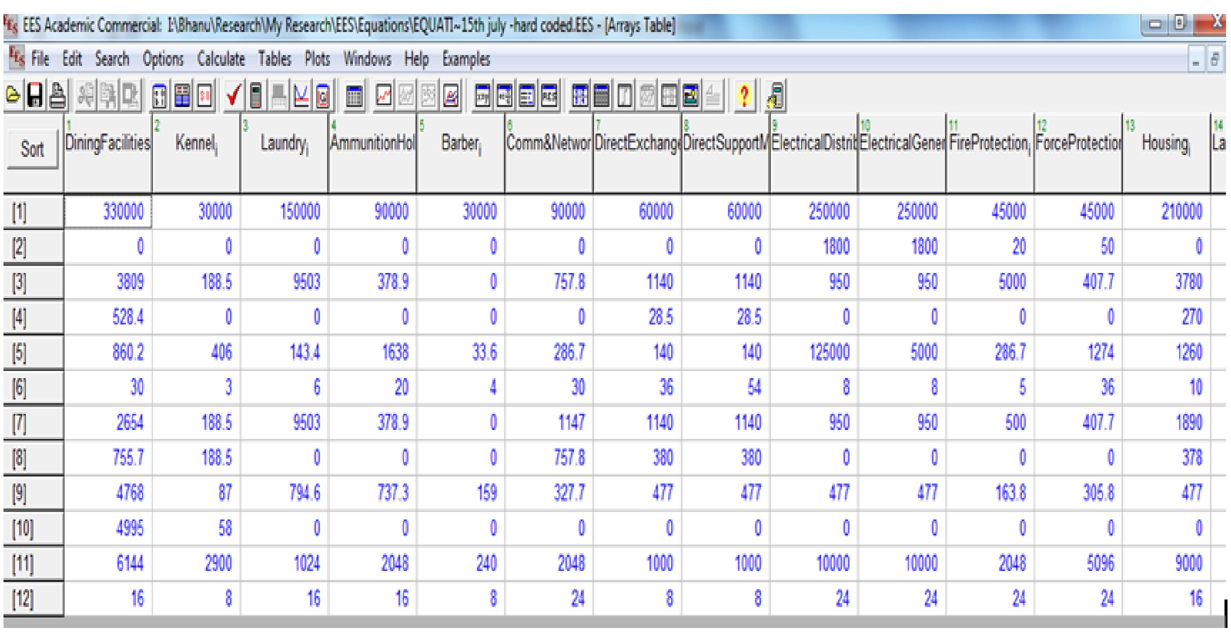
Figure 2: Constants used

## 3.3 Results

Table 3 shows the output of the EES code which is the cumulative total consumption/generation across all 40 facilities modeled. An output of the EES code execution is shown in Figure 3 below. Each of the 12 array values shown in Figure 3 correspond to the 12 parameter values that were discussed earlier in the section.

Table 3: Total Consumption/Generation numbers across all 40 facilities

| | | |
|---|---|---|
| Power consumed(kW) = 3459.5 | Storage Area(Sq.Ft)= 5721 | Food consumed(lbs.)=8823 |
| Power to be generated(kW) = 3862.29 | Support Personnel=504 | Area(Sq.ft)=137169 |
| Fuel consumed(Gal)= 4127.12 | Gray water generated(Gal)=31781 | Maintenance hours= 409 |
| Potable water consumed (Gal)= 45604.7 | Black water generated(Gal)=9473 | Total Population= 1104 |
| Bottled water consumed (Gal) = 3089.8 | Solid waste generated(lbs.)=18160 | |



| Sort | 1 DiningFacilities | 2 Kennel | 3 Laundry | 4 AmmunitionHol | 5 Barber | 6 Comm&Networ | 7 DirectExchange | 8 DirectSupportM | 9 ElectricalDistrib | 10 ElectricalGener | 11 FireProtection | 12 ForceProtectio | 13 Housing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [1] | 330000 | 30000 | 150000 | 90000 | 30000 | 90000 | 60000 | 60000 | 250000 | 250000 | 45000 | 45000 | 210000 |
| [2] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1800 | 1800 | 20 | 50 | 0 |
| [3] | 3809 | 188.5 | 9503 | 378.9 | 0 | 757.8 | 1140 | 1140 | 950 | 950 | 5000 | 407.7 | 3780 |
| [4] | 528.4 | 0 | 0 | 0 | 0 | 0 | 28.5 | 28.5 | 0 | 0 | 0 | 0 | 270 |
| [5] | 860.2 | 406 | 143.4 | 1638 | 33.6 | 286.7 | 140 | 140 | 125000 | 5000 | 286.7 | 1274 | 1260 |
| [6] | 30 | 3 | 6 | 20 | 4 | 30 | 36 | 54 | 8 | 8 | 5 | 36 | 10 |
| [7] | 2654 | 188.5 | 9503 | 378.9 | 0 | 1147 | 1140 | 1140 | 950 | 950 | 500 | 407.7 | 1890 |
| [8] | 755.7 | 188.5 | 0 | 0 | 0 | 757.8 | 380 | 380 | 0 | 0 | 0 | 0 | 378 |
| [9] | 4768 | 87 | 794.6 | 737.3 | 159 | 327.7 | 477 | 477 | 477 | 477 | 163.8 | 305.8 | 477 |
| [10] | 4995 | 58 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| [11] | 6144 | 2900 | 1024 | 2048 | 240 | 2048 | 1000 | 1000 | 10000 | 10000 | 2048 | 5096 | 9000 |
| [12] | 16 | 8 | 16 | 16 | 8 | 24 | 8 | 8 | 24 | 24 | 24 | 24 | 16 |

Figure 3: Individual facility Consumption/Generation numbers

## 4. Future Work

To fully develop a versatile base camp modeling tool, it will be necessary to apply these mathematical models to detailed engineering analysis tools as well as methods to layout and interact with the models. Several open source software packages and tools are being analyzed to put together a larger framework for creating a base camp development tool.

### 4.1 SysML Model

SysML is a graphical modeling language created by The Object Management Group (OMG), used to specify, analyze, design, and verify complex systems [7]. The SysML language is an extension of UML and is based on object-oriented concepts for creating models of physical systems using well defined visual constructs. The following language constructs are used by SysML for representing the system behavior:

1. Activity diagrams depict the behavior of inputs, outputs, sequences, and conditions involved with the system
2. Sequence diagrams model the flow of logic between actors and a system or its components
3. State machine diagrams uses the finite state transition systems to model the discrete behavior involved within the system
4. Parametric diagrams allow representing mathematical relationships existing within the system

The first three constructs represent the behavioral modeling involved in the system and the last one is used to set up mathematical relationships between the properties of a system and its components. SysML is primarily a systems engineering tool for visualizing the conceptual framework and architecture of a complex system. While SysML provides a method for enhancing the understanding of a system, the language does not give the option to integrate different types of models required for complex analysis. Therefore, the SysML model uses the mathematical model to generate the interactions and parametrics (Figure 5 and Figure 6) needed for the execution of the visual model.

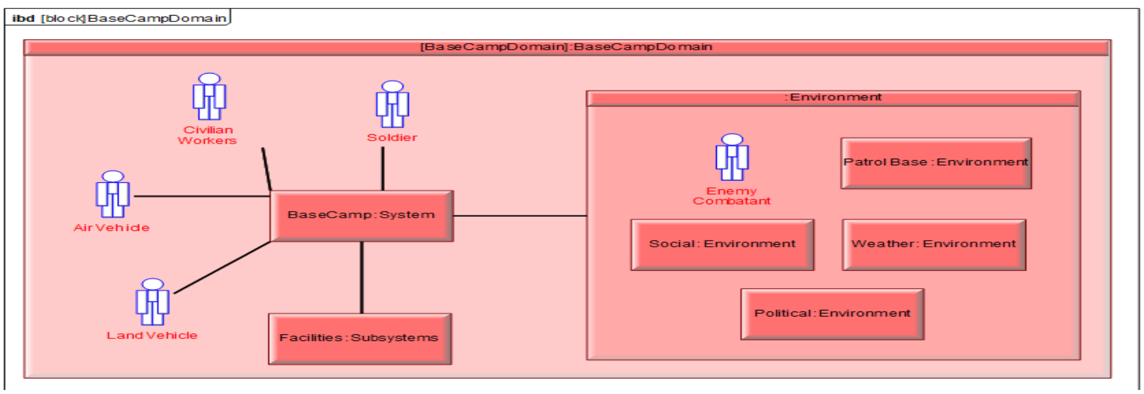



Figure 4 [8]: Base Camp Domain

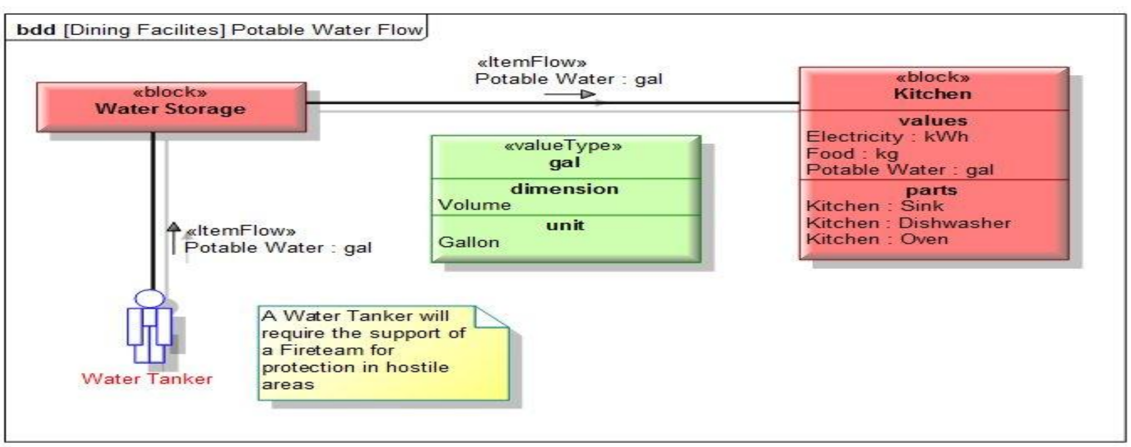



Figure 5 [8]: Interactions between Facilities

## 4.2 GEOBEST and OpenDSS

The Geographical Base Engineer Support Tool (GeoBEST) is a software package developed by the U.S. Army's Engineering Research and Development Center (EDRC). The tool is a 2D and 3D modeling application for assisting in the design of base camps. GeoBEST allows a user to create a geo-referenced site plan and then export the layout for detailed design and analysis with existing tools such as AT Planner (Anti-Terrorist Planner) and TCMS/AFCS (Theater Construction Management System/Army Facilities Components System) [9]. With regard to the architecture of this system, GeoBEST will be used as a graphic modeling tool that will be incorporated into the overall product. With it, the user may visualize and make manual changes to the automatically assembled base camp design before the final 3D model is rendered.

The Distribution System Simulator (DSS) is an open-source tool with its own language OpenDSS[10] which may be used to design and model electrical distribution systems. OpenDSS provides a way to take information about electrical loads of base camp facilities (from the mathematical model) and distances between facilities (from GeoBEST) to create an electrical distribution system design for the base camp. OpenDSS does not automatically create an electrical distribution system, but facilitates the design process by providing a framework for modeling the distribution system and a solver for calculating losses and other relevant information. OpenDSS may be used to manually create and test an electrical grid design, or it may be incorporated into an automated electrical distribution system design package as proposed here.

## 4.3 Virtual Engineering

Virtual engineering provides a means of creating a replica of a physical system in a computer-generated virtual environment. The model underlying such an environment can be a combination of geometric, physical, qualitative, and quantitative data associated with the system [11]. In addition, it provides a platform to present all the information regarding the design with a rich graphical user interface to provide stakeholders a means to interact with the model. The future scope of the mathematical model is to use it within the VE-Suite framework [12], an open-source software package developed at Iowa State University to facilitate virtual engineering. VE-Suite performs engineering analysis by providing interfaces that allows software packages to exchange data in a comprehensive design environment [13]. The architecture of VE-Suite (Figure 6) is composed of three core engines: *VE_Xplorer*, which is the engine that provides graphical support for creating the virtual environment and also can be used to display the simulation under observation. *VE_Conductor* forms the front end user interface and *VE_CE* is the computational engine which provides a platform to link open a variety of computational tools, including commercial analysis software packages, with the virtual engineering framework.

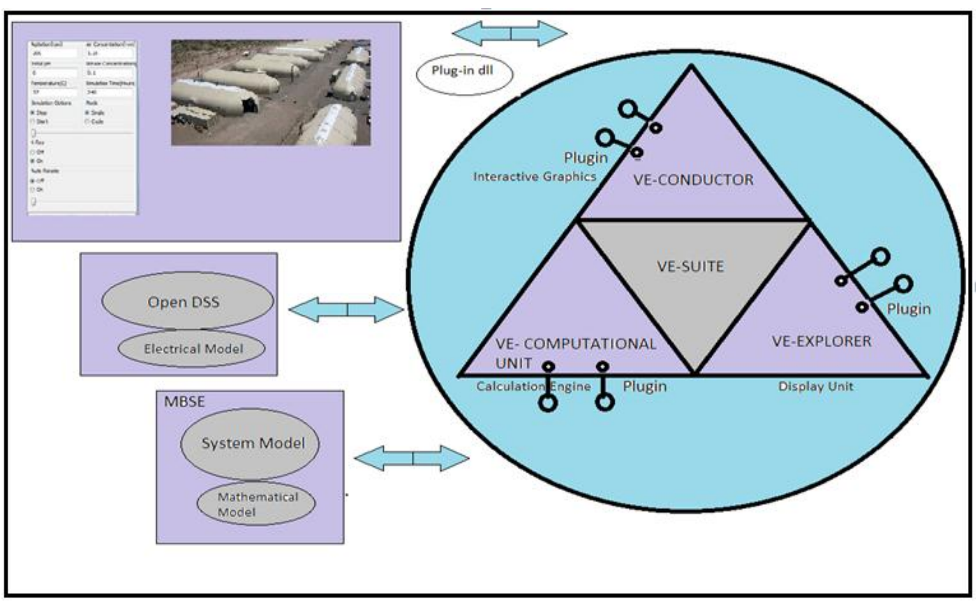



Figure 6: VE-Suite architecture [13]

Using the computational tools accessible through the front-end user interface, a complete model of the base camp can be generated from user inputs to provide an optimized base camp design. The user may then tweak this design at will before finally submitting it to VE-Suite to be rendered as a full 3D interactive virtual walkthrough model.

## 4.4 Overall System Architecture

Evolutionary Algorithms (EAs) are computational problem solving tools which are often used in complex optimization problems to find solutions with high utility. In this case, EAs will be used to solve some of the more challenging problems in base camp planning. After the mathematical model is used to solve for the overall resource requirements of the base, the specific combination of structures (facilities) to fulfill resource needs can be solved for by an EA. The mathematical model can be used as the evaluator for the EA by finding the resources required for the overall base. The EA can use this model to find the right combination of specific structures to satisfy all base camp needs while keeping the overall system lean. Any additional constraints that may be anticipated, such as occasional overflow, may be taken into account so that extra facilities are available when needed.

In addition, an EA can be used to help determine the placement of structures on a map. With the appropriate topographical data available in a digitized form as well as data for wind direction and other appropriate information, an EA could place water and waste facilities in optimum locations. Buildings could be automatically spaced at specified distances, clustered and positioned relatively to one another as appropriate. Finally, the user may still make any required changes to the suggested design manually before the electrical grid is generated and a final detailed design is produced.

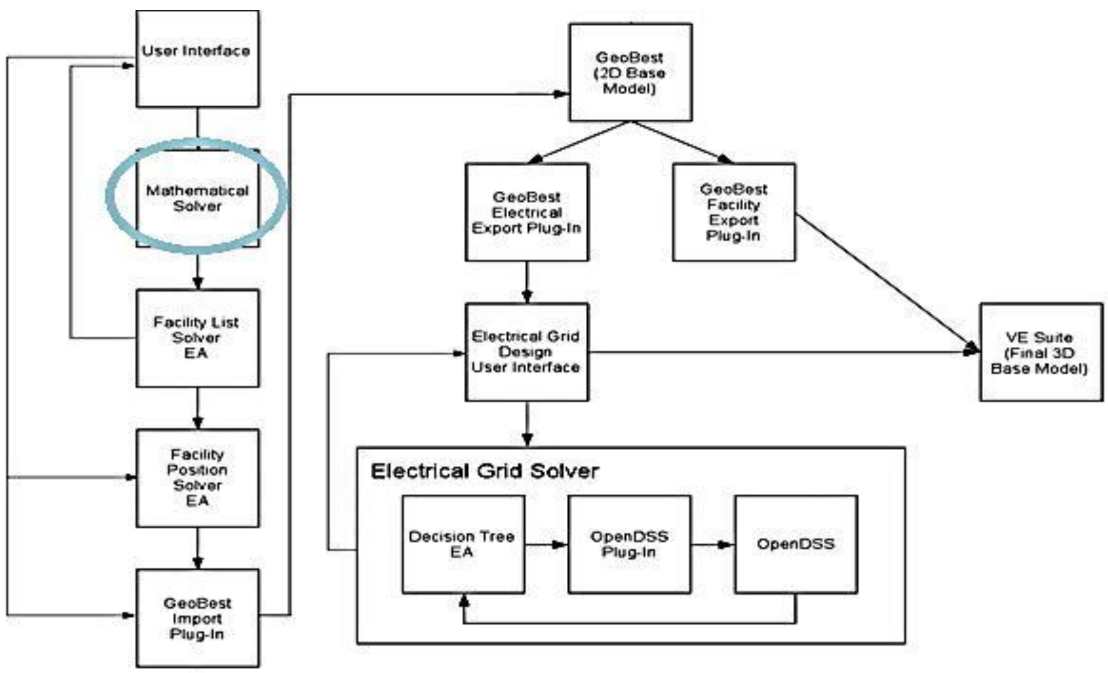



Figure 7: Architecture overview for FOB

Finally, the electrical grid can also be designed automatically and efficiently using an EA. FOBs have commonly had problems with inefficiently designed electrical systems. Problems such as wet-stacking of diesel generators occur due to haphazard, rushed, or last-minute structure assembly. In conjunction with OpenDSS, an EA could be designed to evolve highly effective electrical grids quickly for base planners and field engineers. Distances between structures and power requirements (loads) can be input as parameters, as well as the types of generators and transformers currently on hand. The EA with integrated OpenDSS could then be used to solve for the most efficient electrical grid design. Buildings may be designed in clusters with individual generators, or the entire base integrated into a single grid based on the user's specification. It is important to note that the EA will probably be responsible for generating only a 'naked' grid design void of protection systems (for the sake of expediency in completing the project); therefore an engineer would be required to finalize the design prior to its implementation in the field.

The overarching goal of this research is to develop a system of computational techniques to design and model FOBs to improve effectiveness and efficiency in the field. It is also necessary for the platform to be user friendly and accessible for base camp planners. A general architecture overview of the envisioned completed system is given above in Figure 7. Use of the planning tool will occur in several primary stages:

1) User inputs mission-specific facilities, number of soldiers, likely base service duration, a topographical map and wind data
2) Mathematical model (discussed in this paper) generates a list of required resources
3) EA1 selects structures which satisfy resource requirements for water, waste, power, maintenance, support personnel, etc.
4) EA2 places buildings
5) User is prompted to make changes if necessary within the graphic modeling environment (GeoBEST)
6) EA3 creates electrical system
7) User is prompted to make changes if necessary
8) Final 3D walkthrough model is assembled in VE Suite

The general scope of this paper centers upon the mathematical model which has been developed for representing base camp subsystems (facilities) as objects linked by resource utilization interrelationships. In future work, a system of computational methods and solvers (some of which, such as OpenDSS and GeoBEST, are pre-existing) will be merged into a single cutting-edge tool for base camp planners. This tool will be extremely resourceful, and should be capable of automating the greater majority of the design process using advanced optimization techniques.

## 5. Conclusions

A model of the interrelationships between subcomponents (facilities) within an FOB is accomplished with a mathematical model consisting of a large set of linear equations. This model is used to estimate the resources required for each subsystem and for the overall base camp. This information can be used immediately by planners to improve FOB designs as well as logistical support systems. This information can also be used within an advanced design tool which has been proposed for automating and optimizing the design process of FOBs. Finally, a 3D virtual walkthrough model may be generated from this design. Such a tool would be very useful for base camp planners in visualizing an FOB before it is created, or to visualize proposed changes to an existing FOB. These tools would lead to an increase in efficiency of resource utilization for FOBs, with the goal of reducing government expenditures and decreasing risk exposure to convoys and logistical support personnel.

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