Click here to view PowerPoint presentation; Press Esc to exit

Quick Strategic Force Closure Sensitivity for Multiple Scenarios

Jean M. Mahan, Ph.D. / William H. Key II/Lt Col Robert Thomas Brigantic, Ph.D.
United States Transportation Command, TCJ5-SC
508 Scott Dr, Bldg 1900
Scott AFB, IL 62225
USA
Email: **jean.mahan@hq.transcom.mil / William.key@hq.transcom.mil / Robert.brigantic@hq.transcom.mil**

ASTRACT

A tenant of the U.S. Army Vision for future small scale contingency deployments is rapid force closure. To examine initial concept feasibility from an airlift transportation perspective, U.S. Transportation Command developed a Strategic Airlift Quick-Look Tool. Like other U.S. Quick-Look tools, this tool allows assessments to be made quickly using the best available data and planning factors flexibly defined by the analyst. This tool is unique in that it allows for the examination of up to 56 different scenarios simultaneously under various transportation constraints which impact closure. When evaluating future concepts, many variables are still "soft." For the transportation analyst, these "fuzzy" variables may include the size of the dedicated airlift fleet, size of deploying force, level of hazardous cargo processing required, available en route infrastructure, etc. In order to assess the essence of the future transportation challenge, the analyst must take a broader look and examine the relative sensitivities of these variables on closure estimates. The purpose of this presentation is to share a "Quick-Look" approach to examining multiple scenarios at once to assess closure potential relative to variables of interest.

INTRODUCTION

In early 2001, United States Transportation Command analysts were tasked to assess the force closure of a light infantry brigade from seven specific candidate home stations to eight potential "hot spots" around the world, a total of 56 scenarios. To conduct this assessment, two existing high fidelity simulations were available. However, both these tools are data intensive and require significant manpower to set-up, run and analyze the results for just a single excursion of a single scenario. Early analysis results were focused on a single scenario (an aircraft onload/offload destination pair) and a limited number of excursions. After several months, sensitivity analysis was still ongoing for the first scenario and the challenge of assessing the remaining scenarios remained untouched, despite an approaching deadline for the entire assessment. From the single scenario work, analysts observed infrastructure and airlift fleet size constraints that were key drivers that could potentially impact the closure results of a large number of the scenarios. To help focus the effort, analysts developed a Strategic Airlift Quick-Look tool that was easy to use, quick to set-up, and provided results that could be quickly assessed. Results from the "Quick-Look" were used to address the impact of constraints and to focus the detailed analysis on selected scenarios.

APPROACH

The original planning parameters for the Strategic Airlift Quick-Look tool envisioned a specifically defined force size to be deployed, a particular airlift fleet size for deploying the force, a predetermined portion of the fleet required to move hazardous cargo loads, and the use of standard Air Mobility Command Planning Factors for payloads, aircraft use rates, ground times, etc. With a defined force, fleet, routing, and planning factors, the computation of closure estimates is straight forward using standard airlift throughput formulas. Microsoft Excel was selected as the venue for the tool simply because the expertise to quickly prototype a user friendly tool using Excel existed in house. Excel has

Report Documentation Page	*Form Approved OMB No. 0704-0188*

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 FEB 2005	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Quick Strategic Force Closure Sensitivity for Multiple Scenarios	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **United States Transportation Command, TCJ5-SC 508 Scott Dr, Bldg 1900 Scott AFB, IL 62225 USA**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001758, NATO RTO-TR-SAS-027 Handbook on the Analysis of Smaller-Scale Contingency Operations in Long Term Defence Planning (Manuel de lanalyse des opérations de circonstance de moindre échelle pour la planification de la défense à long terme)., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**23**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

many built-in features such as drop down lists, buttons, checkboxes and the capability for integrated graphics. The initial prototype of the tool was used to educate U.S. Transportation Command leadership on the impact of key variables on force closure. The power of the Strategic Airlift Quick-Look tool was its ability to quickly and consistently depict multiple scenarios over a wide range of "what-ifs" providing on-the-fly sensitivity analysis. What remains constant throughout the excursions is the fundamental equations used to compute closure results. Without making the tool overly cumbersome to use or understand, the Strategic Airlift Quick-Look tool quickly matured to provide maximal "what-if" capability. Additionally, the tool provided not only closure estimates, but also, constraint identification, and estimates of infrastructure requirements and daily throughput. The key with this approach is that results for a number of scenarios, not just one, are simultaneously computed and graphically displayed. The what-if feedback to the analyst or leadership audience is immediate and the visual presentation makes it easy to understand.

DECOMPOSING THE PROBLEM

The methodology is relatively straight forward. It includes: defining relevant variables, computing fleet closure potential, determining infrastructure requirements to support fleet closure potential, identifying airfield throughput supportable by actual airfield infrastructure, and then displaying results for the user. The majority of the relevant variables can be user defined. Infrastructure requirements are represented by Maximum on Ground (MOG) which is defined as the maximum number of aircraft a location can process, within standard planning times, at one time. This capacity can additionally be restricted by the number of aircraft that can be on the ground at on given time while loaded with hazardous cargo aboard, generally defined in terms of explosive cargo. Hazardous cargo capacity will be referred to as Hot Cargo MOG. The tool computes results for a total of 42 scenarios, rather than 56, primarily due to limited computer screen real estate. However, the result matrix of 6 onloads or aerial port of embarkations (APOE's) and 7 offloads or aerial port of debarkation (APOD's) is sufficient to cover the general geographic locations of interest for the purpose of the analysis. Results are available to the user are in the form of a Constraint Matrix for all 42 scenarios and a Graphic display for one or up to 42 scenarios of the following values: Fleet Closure Potential (days), Constrained Closure (days), MOG or Hot Cargo Requirements for APOE's or En Routes, and MOG for APOD's.

Computing Fleet Closure Potential:

1. Define total force deployment requirement (Tons and Pax)

2. Define Fleet: number of aircraft of each type, USE rates, and payloads. USE rate is a planning factor for hours per day an aircraft can fly. This factor takes maintenance, crews, routing, etc into account. Define average payloads (Tons and Pax) for each aircraft type.

3. Define ground times for onload, en route, and offload stops.

4. Define scenario round trip (onload to offload) distance for each scenario onload/offload pair. For each aircraft type, determine number of en route stops and aircraft flying speeds to associate with a matrix of round trip flying distances from 2,000 to 28,000 NM.

5. Calculate round trip flying time (RTFT) for each aircraft type which equals round trip distance divided by aircraft flying speed.

6. Calculate round trip ground time (RTGT) for each aircraft type: onload ground time + (number of en routes) x (en route ground time) + offload ground time.

7. Compute round trip cycles (RTC) per day for each aircraft type: Minimum of 24/(RTFT+RTGT) or USE/RTFT, which for most typical scenarios will be limited by USE/RTFT.

8. Compute daily throughput for each aircraft type: (RTC/day) x (aircraft payload).

9. Compute daily fleet throughput: Sum over all aircraft types the (daily throughput) x (number of fleet aircraft).

10. Compute fleet closure potential for scenario (pax or tons): (total force deployment requirement)/(daily fleet throughput).

Computing Infrastructure Requirements to support fleet closure potential:

1. Define queueing efficiency which is an AMC planning factor for how efficiently aircraft can be scheduled into the parking at an airfield. This planning factor is less than or equal to one.

2. Onload MOG Requirement: Sum over all aircraft types [(round trip cycles/day/aircraft) x (# of fleet aircraft) x (onload ground time)/24]/(queueing efficiency)

3. En Route MOG Requirement: Sum over all aircraft types [(round trip cycles/day/aircraft) x (# of fleet aircraft) x (en route ground time)/24] /(queueing efficiency). If the en route airport is used inbound and outbound this number should be doubled.

4. Offload MOG Requirement: Sum over all aircraft types [(round trip cycles/day/aircraft) x (# of fleet aircraft) x (offload ground time)/24] /(queueing efficiency)

5. Onload Hot Cargo MOG Requirement: Sum over all aircraft types [(% loads carrying hot cargo) x (round trip cycles/day) x (# of aircraft) x (onload ground time)/24]/(queueing efficiency).

6. En Route Hot Cargo MOG Requirement: Sum over all aircraft types [(% loads carrying hot cargo) x (round trip cycles/day) x (# of aircraft) x (en route ground time)/24]/(queueing efficiency). En route hot cargo parking is only required on the inbound leg to the APOD.

Identifying airfield throughput supportable by actual airfield infrastructure:

Understanding the closure capacity of an origin-destination pair amounts to evaluating the round trip cycle the aircraft will travel and evaluating each airfield in the round trip route to determine what level of throughput that node can support. The airfield throughput capacity equation is evaluated for each airfield to determine the throughput capacity at onloads, en routes, and offloads. The same equation is also used to evaluate the hot cargo constraint for the onloads and en routes.

Airfield Throughput Capacity = [(Defined Airfield MOG)/(Airfield MOG Required to Maximize Fleet Potential)] x Fleet Throughput Potential

If one or more airfields limit the fleet's throughput, the airfield with the minimum capacity will be identified as the overriding infrastructure constraint in the route and the airfield's throughput level will be referred to as the constrained scenario throughput. The constrained scenario throughput is simply equal to the fleet throughput potential if none of the airfield's limit the fleet throughput.

BUILDING THE TOOL

The main user input screen is shown in Figure 1. The result graphic allows for the comparison of all origin to destination pairs, quickly identifying the best options to meet the desired objective. Also displayed on the initial screen panel are the default inputs for each scenario. Results for closure potential, constrained closure, infrastructure requirements can all be displayed on the same graph depending on which results the user has selected to view.

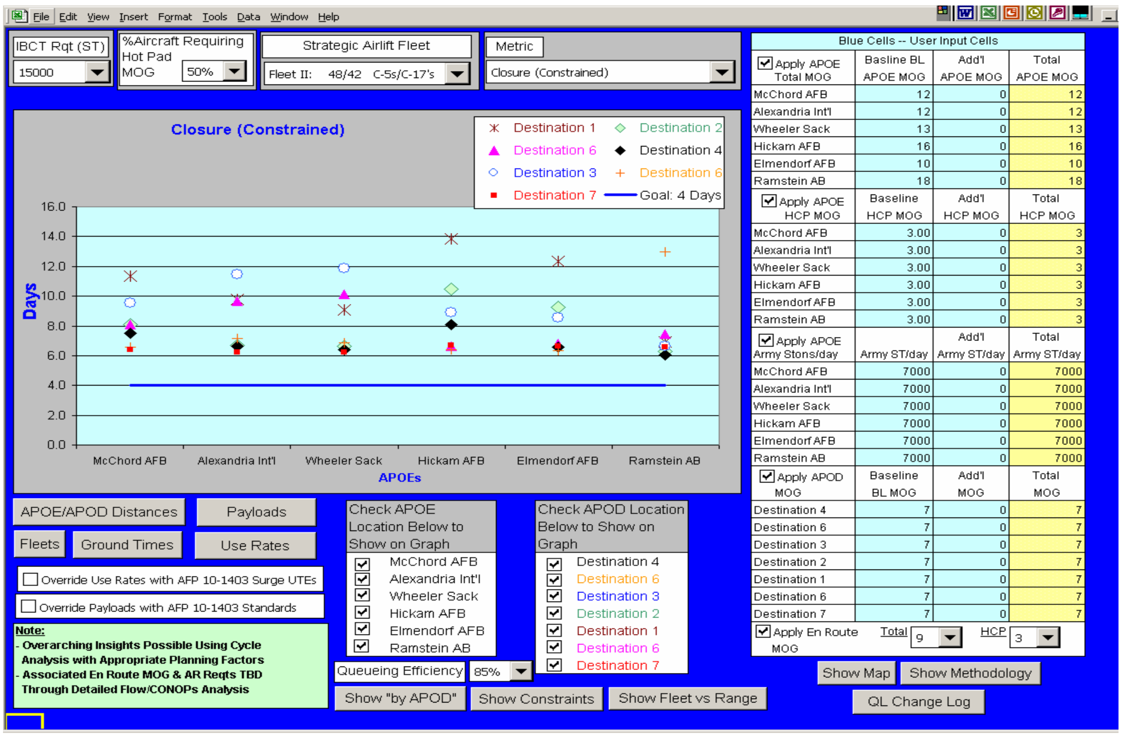


Figure 1. Main User Input Screen With Variable Inputs

Primary variables included the airfleet, the weight of the deploying force and hot cargo percentage. This are all available from the main screen. Figure 2 shows the user screen for defining the airfleet which is accessed with a button labeled *Fleets*. The Strategic Airlift Quick-Look tool was designed to evaluate up to 4 user-defined airfleets of just 3 aircraft types: C-5, C-17 and WB Pax. The different levels could represent either different withhold/mobilization rates or even future procurement levels. The weight of the deploying force and the Hot Cargo % are changed using a drop down box.

Fleet Label	C-5	C-17	WB Pax	User Defined Fleets
Fleet I:	14	20	0	Fleet I: 14/20 C-5s/C-17's
Fleet II:	48	42	0	Fleet II: 48/42 C-5s/C-17's
Fleet III:	60	84	0	Fleet III: 60/84 C-5s/C-17's
Fleet IV:	0	144	0	Fleet IV: 0/144 C-5s/C-17's

Blue Cells -- User Input Cells

Figure 2. User Screen for User-Defined Airfleets

User defined scenario inputs include airfield MOGs which are defined on the far right of Figure 1. The ability to select or fine tune which APOE and APOD scenario pairs displayed on the graph is provided by using the check boxes at the bottom of the main screen just below the graph. The user may select no scenario in which case the graph will be empty, one scenario pair, or up to all 42 scenarios. The setup is flexible enough that it allows for display of all destinations associated with a single APOE or all onloads associated with a single APOD, depending on the user's desires.

The tool provides the user the flexibility to define the set of APOE and APOD pairs to be evaluated. The Origins, Destinations, and Distance are all user definable in a Matrix shown in Figure 3. The tool automatically labels the output graphs and contraint matrix with these labels. The tool depends on the user to input a distance in the matrix that represents approximately ½ the round trip flying distance. The distance ideally should include all deviations required for routing.

1/2 Round Trip Flying Distance or approx "Onload-Offload Flying Distance"	Destination 4	Destination 6	Destination 3	Destination 2	Destination 1	Destination 6	Destination 7
McChord AFB	6554	4599	8500	7000	10000	7000	3650
Alexandria Int'l	5099	6175	10100	5600	8700	8600	2162
Wheeler Sack	3998	5860	10500	5100	8000	9000	2180
Hickam AFB	7003	3870	7800	9300	12300	4680	5450
Elmendorf AFB	4593	3337	7500	8150	10900	5800	4875
Ramstein AB	1000	11500	5000	2700	5900	6500	4550

Blue Cells -- User Input Cells

Figure 3. User Input Screen for Origins, Destinations, and Distances.

For planning factors such as Payloads, USE Rates, and Ground times, the user has the capacity to define the variables or to use the standard planning factors. The planning factors are available to the user from the main screen via a button. The output constraint matrix shown in Figure 4 identifies the specific contraint associated with each scenario evaluated. If the airfield infrastructure is able to 100% support the potential fleet closure, the fleet will be identified as the constraint; otherwise, the airfield infrastructure node that constrained the closure will be identified.

Constraint LEGEND	
Symbol	Description
HCP	APOE Hot Cargo MOG
APOE	APOE Total MOG
APOD	APOD MOG
ER MOG	Total En Route MOG
ER HCP	En Route Hot Cargo MOG
Army	Army ST/day
Fleet	Fleet

CONSTRAINT MATRIX	Destination 4	Destination 6	Destination 3	Destination 2	Destination 1	Destination 6	Destination 7
McChord AFB	FLEET	APOE HCP	FLEET	FLEET	FLEET	FLEET	APOE HCP
Alexandria Int'l	APOE HCP	FLEET	FLEET	APOE HCP	FLEET	FLEET	APOE HCP
Wheeler Sack	APOE HCP	FLEET	FLEET	APOE HCP	FLEET	FLEET	APOE HCP
Hickam AFB	FLEET	APOE HCP	FLEET	FLEET	FLEET	APOE HCP	APOE HCP
Elmendorf AFB	APOE HCP	APOE HCP	FLEET	FLEET	FLEET	FLEET	APOE HCP
Ramstein AB	APOE HCP	FLEET	APOE HCP	APOE HCP	FLEET	FLEET	APOE HCP

Figure 4. Contraint Matrix

CONCLUSION

The Strategic Airlift Quick-Look tool was successfully used by the U.S. Transportation Command to identify critical factors associated with the Army Vision. In short, the tool was used to demonstrate the demanding nature of the Army Vision and the challenges that must be addressed to make it viable. For instance, the Quick-Look tool demonstrated the significant impact that hot cargo requirements has on overall force closure. Reducing the hot cargo requirement can greatly reduced force closure time. Likewise, the tool vividly demonstrated the importance of reducing the overall weight of the Army brigade to be deployed. Lastly, the tool was used to show the huge impact that overall distance to the destination has on force closure. Ultimately, these insights and results were used to brief the highest levels of the U.S. Transportation Command and the U.S. Army.

Quick Strategic Force Closure Sensitivity For Multiple Scenarios

Jean M. Mahan
US Transportation Command
Joint Mobility Analysis Center

Background

- Emerging Defense Requirements
  - Evaluating Future Force Deployment Concepts
  - Small Scale Contingencies
  - Rapid Force Closure -- Tenant of Army Transformation
- USTRANSCOM Required to Evaluate Future Concepts From a "Mobility" Perspective
  - Numerous Fuzzy/Undefined Variables
- Multi-Agency Study Effort – 9 Months
  - Study Required Examination of 42 Scenarios With Sensitivity Analysis on Fleet Size, Reqt Size, etc

Potential Global Response

Background

- 4 Months of Initial Analysis
  - Focused on One Scenario Only
  - Developed Assumptions and Detailed Simulation Setup
  - Leadership's Continued Questions Slowed Progress
  - Produced Initial Results But Little Sensitivity Analysis
- Study Deadline Approaching and Leadership Visibility High - Current Progress Only Scratched the Surface
- Requirement to Accelerate Study Effort and Facilitate Ongoing Leadership Insights Prior to Study Completion

Background

- Requirement for New Approach to Produce Consistent Results Quickly
  - Quick Initial Assessments of Concept Feasibility for All 42 Scenarios
  - Quick Sensitivity Analysis Across Many Scenarios Simultaneously
  - Identification of Overall and Scenario Specific Limiting Factors
- New Approach – Rapid Development of "Quick-Look" Tool
  - Interactive Excel Based Tool
  - Based on Airlift Cycle Analysis and Mobility Planning Factors
  - Quick Interactive Visual Results
  - Tool Used With Leadership to Facilitate Development of Insights
- Initial Results Used to Scope The Study Effort for Rapid Completion
  - Detailed Analysis Focused On Selected Scenarios
  - Both Quick Look and Detailed Analysis Produced Consistent Results

Future Concept Uncertainties

- Many Potential Contingency Locations
  - Drives Examining Representative Offload Locations
- Force Outload Locations Undetermined
  - Drives Examining Several Good Candidates
- Size of Airlift Fleet Dedicated to Small Contingencies
  - Drives Examining Relative Capability of Different Fleets
- Extent of Hazardous Cargo Processing Required
  - Drives Examining Different Levels of Requirement
- Size of Deploying Force
  - Still in Concept Phase
- Availability of En Route and Offload Infrastructure to Support Deployment

Closure Analysis

How Many Days ?

- Closure is Sensitive to Scenario Variables
- Rapid Force Closure is Good, But There is a Limit to How Fast
- Closure Depends on
  - Size of Deploying Force
  - Scenario Distances & Transportation Infrastructure
  - Airlift Fleet Available
- Quickest Closure is Possible When Maximizing Fleet Potential
- Fleet Potential is Maximized When There are No Transportation Infrastructure Constraints

Closure Analysis

How Many Days ?

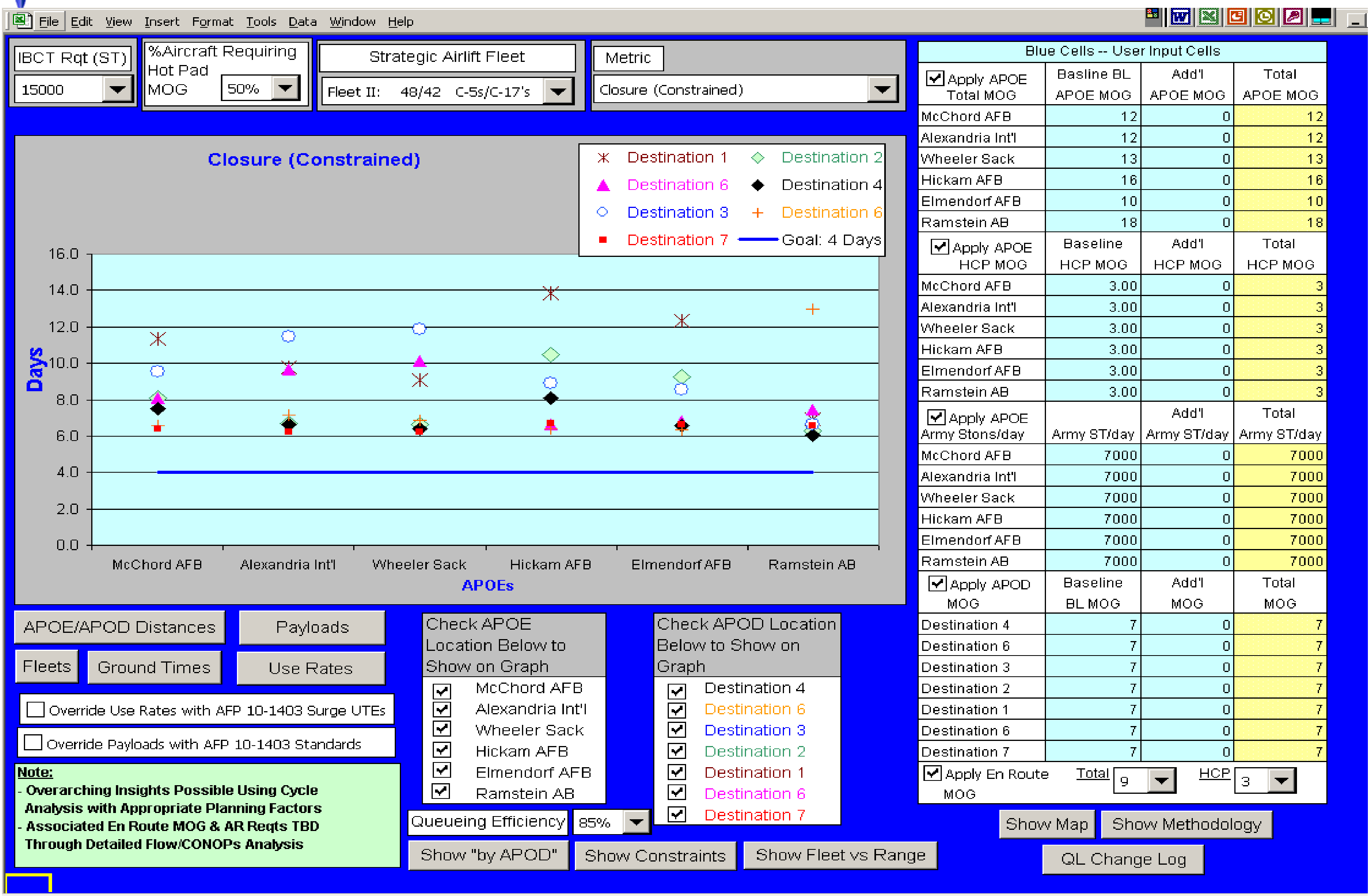
Closure Questions for Given Force, Scenario & Fleet:

1. What is the Quickest Force Closure Possible?
2. How Much Transportation Infrastructure is Required to Maximize Fleet Potential and Achieve Quickest Closure?
3. What is the Actual Force Closure Possible Based on Available Transportation Infrastructure?

Quick Look Tool

- Multiple Scenarios Displayed Simultaneously
- Range of Scenario Variables
- Quick Look Results
  - Closure Potential
  - Actual Closure
  - Transportation System Constraints
  - Infrastructure Required to Reach Closure Potential
- Interactive Visual Presentation Facilitates Comprehension of Issues

Quick Look Tool
Main User Screen



Quick Look Tool

Screen for User-Defined Air Fleets

Fleet Label	C-5	C-17	WB Pax	User Defined Fleets
Fleet I:	14	20	0	Fleet I: 14/20 C-5s/C-17's
Fleet II:	48	42	0	Fleet II: 48/42 C-5s/C-17's
Fleet III:	60	84	0	Fleet III: 60/84 C-5s/C-17's
Fleet IV:	0	144	0	Fleet IV: 0/144 C-5s/C-17's

Blue Cells -- User Input Cells

Quick Look Tool

Screen for Origins, Destinations & Distances

1/2 Round Trip Flying Distance or approx "Onload-Offload Flying Distance"	Destination 4	Destination 6	Destination 3	Destination 2	Destination 1	Destination 6	Destination 7
McChord AFB	6554	4599	8500	7000	10000	7000	3650
Alexandria Int'l	5099	6175	10100	5600	8700	8600	2162
Wheeler Sack	3998	5860	10500	5100	8000	9000	2180
Hickam AFB	7003	3870	7800	9300	12300	4680	5450
Elmendorf AFB	4593	3337	7500	8150	10900	5800	4875
Ramstein AB	1000	11500	5000	2700	5900	6500	4550

Blue Cells -- User Input Cells

Quick Look Tool
Constraint Matrix

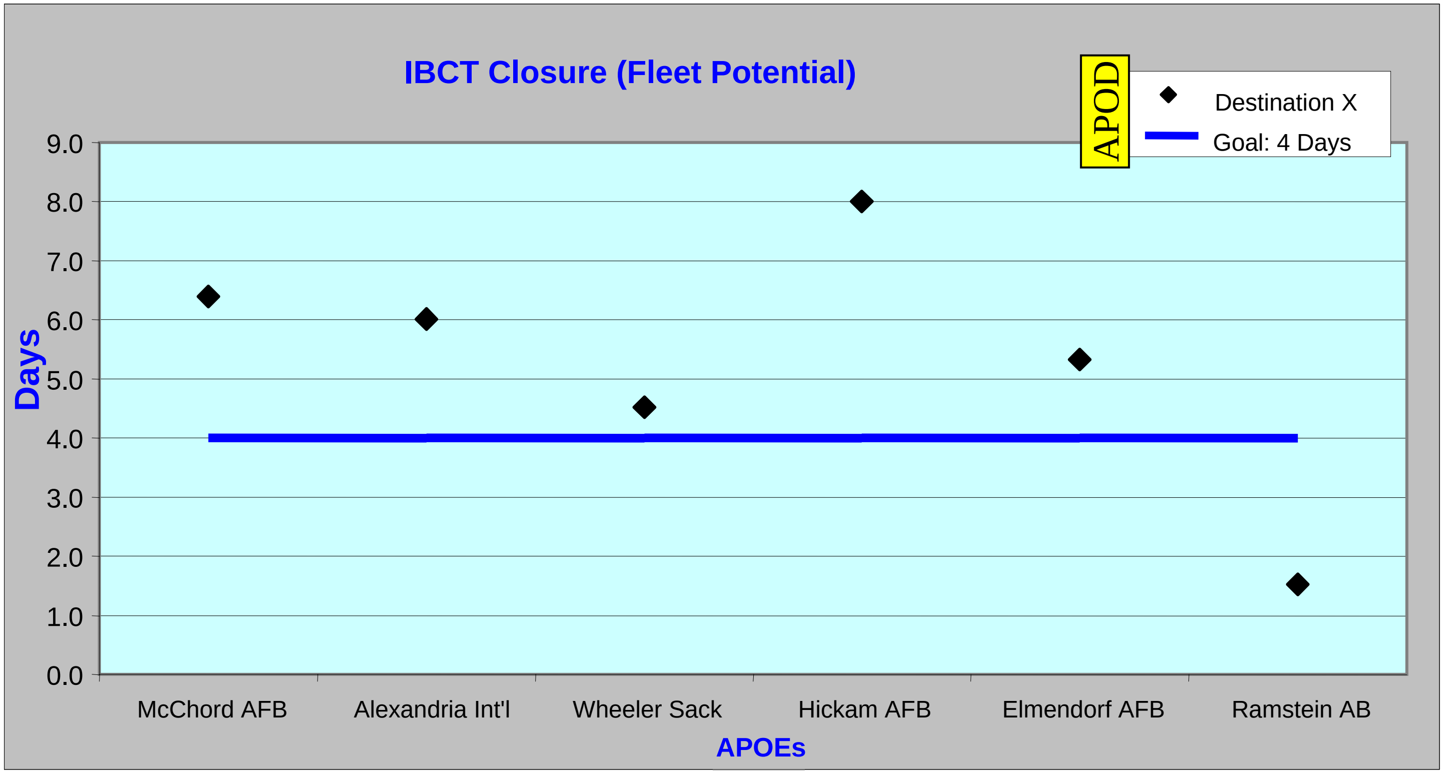
Constraint LEGEND	
Symbol	Description
HCP	APOE Hot Cargo MOG
APOE	APOE Total MOG
APOD	APOD MOG
ER MOG	Total En Route MOG
ER HCP	En Route Hot Cargo MOG
Army	Army ST/day
Fleet	Fleet

CONSTRAINT MATRIX	Destination 4	Destination 6	Destination 3	Destination 2	Destination 1	Destination 6	Destination 7
McChord AFB	FLEET	APOE HCP	FLEET	FLEET	FLEET	FLEET	APOE HCP
Alexandria Int'l	APOE HCP	FLEET	FLEET	APOE HCP	FLEET	FLEET	APOE HCP
Wheeler Sack	APOE HCP	FLEET	FLEET	APOE HCP	FLEET	FLEET	APOE HCP
Hickam AFB	FLEET	APOE HCP	FLEET	FLEET	FLEET	APOE HCP	APOE HCP
Elmendorf AFB	APOE HCP	APOE HCP	FLEET	FLEET	FLEET	FLEET	APOE HCP
Ramstein AB	APOE HCP	FLEET	APOE HCP	APOE HCP	FLEET	FLEET	APOE HCP

Unconstrained Closure
Destination X (Fleet II)

No MOG Constraints

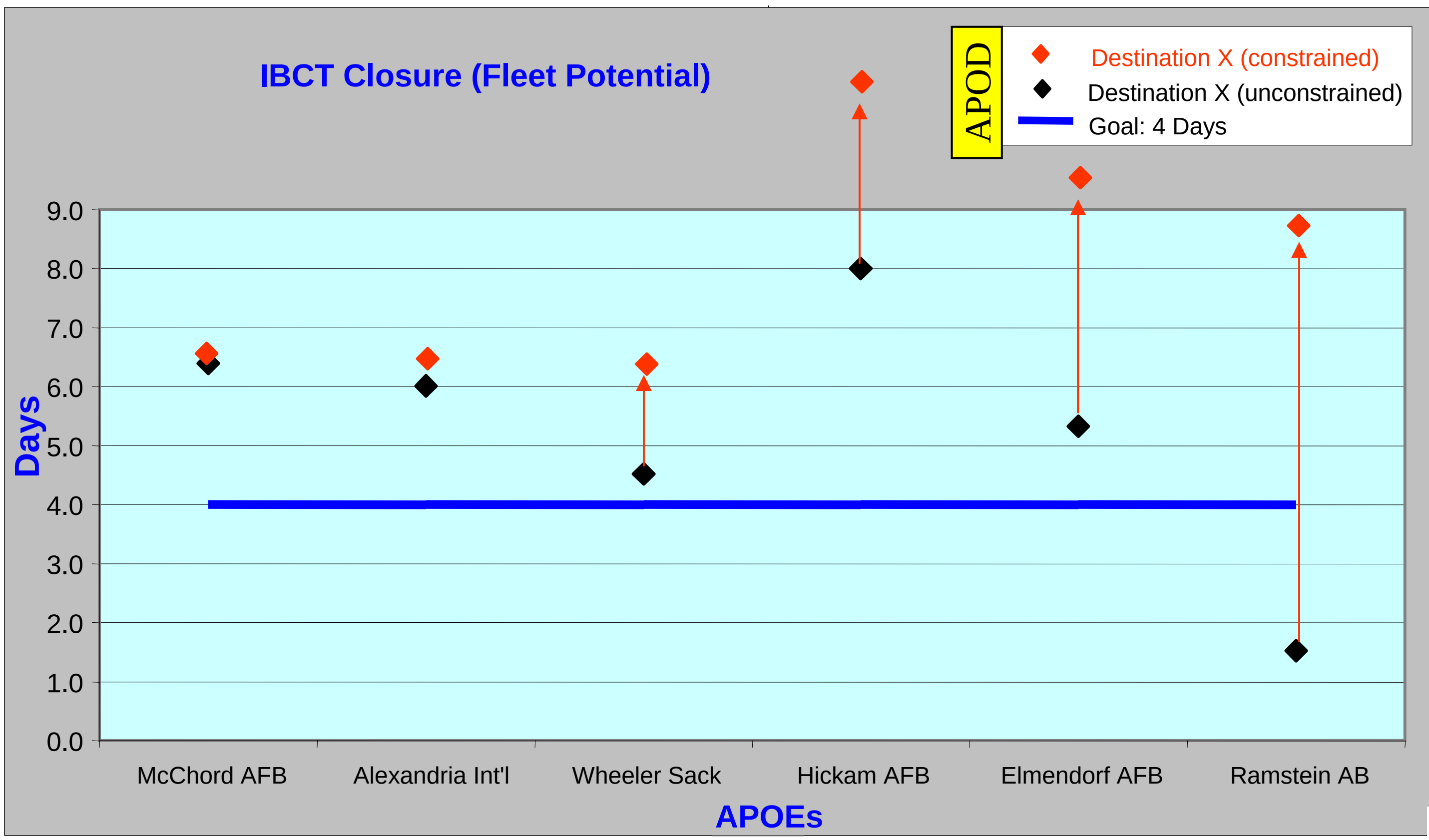
Requirement: 14,500 STONS with 50% Aircraft Requiring Hot MOG



Constrained Closure

Destination X (Fleet II)

IBCT Requirement: 14,500 STONS with 50% Aircraft Requiring Hot MOG



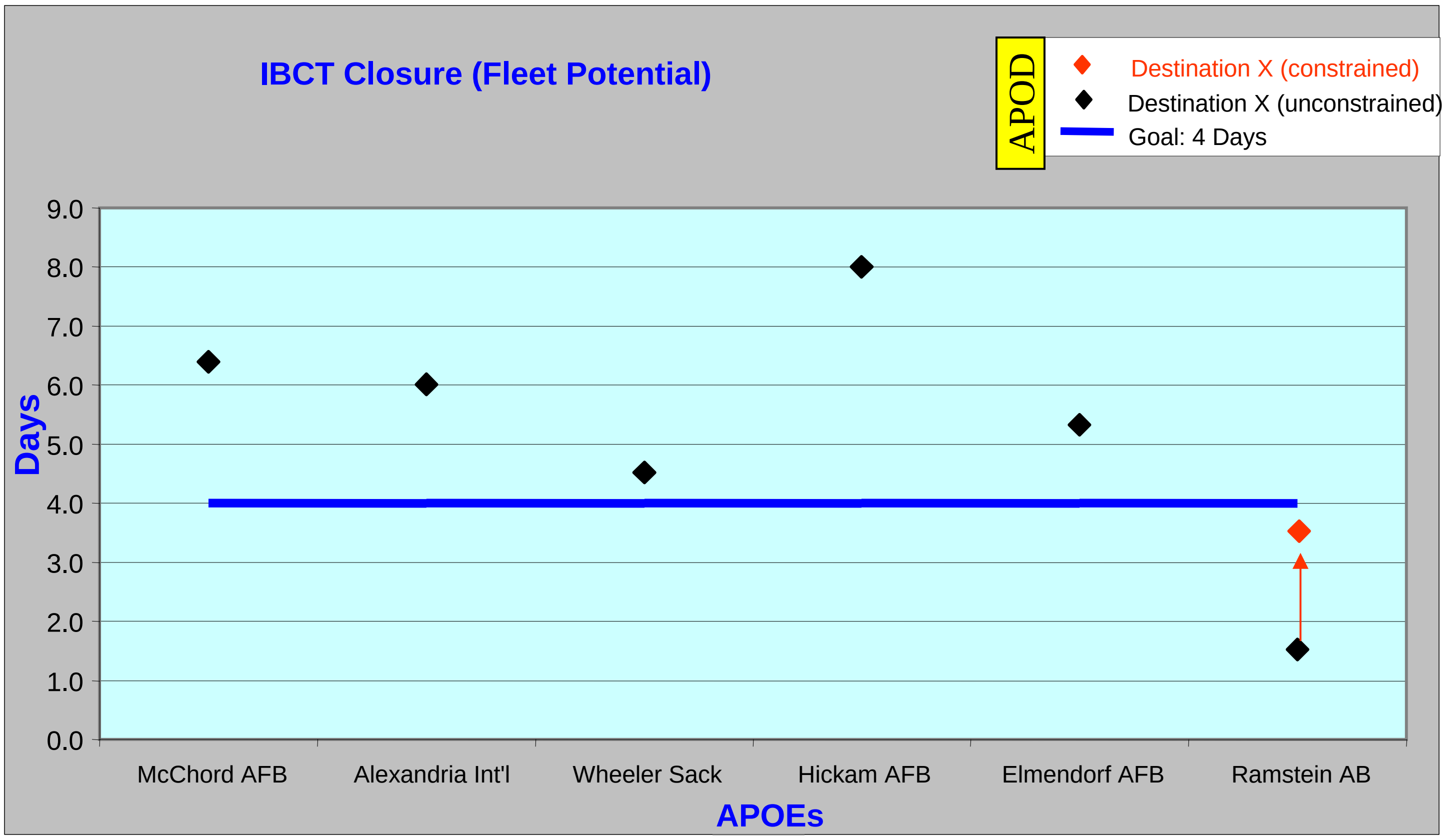
☑ Apply APOE Total MOG	Basline APOE MOG
McChord AFB	9
Alexandria Int'l	7
Wheeler Sack	12
Hickam AFB	12
Elmendorf AFB	12
Ramstein AB	11
☑ Apply APOE HCP MOG	Baseline HCP MOG
McChord AFB	3
Alexandria Int'l	3
Wheeler Sack	3
Hickam AFB	1.66
Elmendorf AFB	2
Ramstein AB	2
☑ Apply APOD MOG	Baseline MOG
Balkans	7
NEA	7
Asia Sub	7
West Africa	7
Deep Africa	7
Pacific Rim	7
South America	7

☑ Apply En Route Hot MOG 3

Constrained Closure

Destination X (Fleet II)

IBCT Requirement: 14,500 STONS with 20% Aircraft Requiring Hot MOG



☑ Apply APOE Total MOG	Basline APOE MOG
McChord AFB	9
Alexandria Int'l	7
Wheeler Sack	12
Hickam AFB	12
Elmendorf AFB	12
Ramstein AB	11
☑ Apply APOE HCP MOG	Baseline HCP MOG
McChord AFB	3
Alexandria Int'l	3
Wheeler Sack	3
Hickam AFB	1.66
Elmendorf AFB	2
Ramstein AB	2
☑ Apply APOD MOG	Baseline MOG
Balkans	7
NEA	7
Asia Sub	7
West Africa	7
Deep Africa	7
Pacific Rim	7
South America	7

☑ Apply En Route Hot MOG 3

Summary

- Quick Look Approach to Assess Transportation Challenges of Future Concepts
- Broad Look at Closure Variables Across Multiple Scenarios Simultaneously
- New Approach of “Quick Look Tool” Not Embraced Until After Tool Was Prototyped and Shown to Leadership
- “Quick Look Tool” Successful For
  - Making Initial Assessment and Recommendations Concerning Army Transformation Goals
  - Identifying Closure Issues
  - Assessing Relative Merit of Different APOE’s