TECOLOTE RESEARCH, INC.
Bridging Engineering and Economics
Since 1973

Cost-Risk Analysis of Satellite Bandwidth Services

Sam Bresnahan

2007 ISPA/SCEA Conference

■ Los Angeles ■ Washington, D.C. ■ Boston ■ Chantilly ■ Huntsville ■ Dayton ■ Santa Barbara
■ Albuquerque ■ Colorado Springs ■ Columbus ■ Ft. Meade ■ Ft. Monmouth ■ Montgomery ■ Ogden ■ Patuxent River ■ Pensacola ■ San Diego
■ Charleston ■ Cleveland ■ Denver ■ New Orleans ■ Oklahoma City ■ Silver Spring ■ Warner Robins AFB ■ Vandenberg AFB

Outline

- **Setting the stage**
- **Conduct the analysis**
  1. Collect data
  2. Build point estimate
  3. Build risk distributions
  4. Specify correlation
  5. Run the simulation
- **View and interpret results**
- **Concluding observations**

Presented at the 2007 ISPA/SCEA Joint Annual International Conference and Workshop - www.iceaaonline.com

TECOLOTE RESEARCH, INC.
Bridging Engineering and Economics
Since 1973

Setting the Stage

What is ECCS?

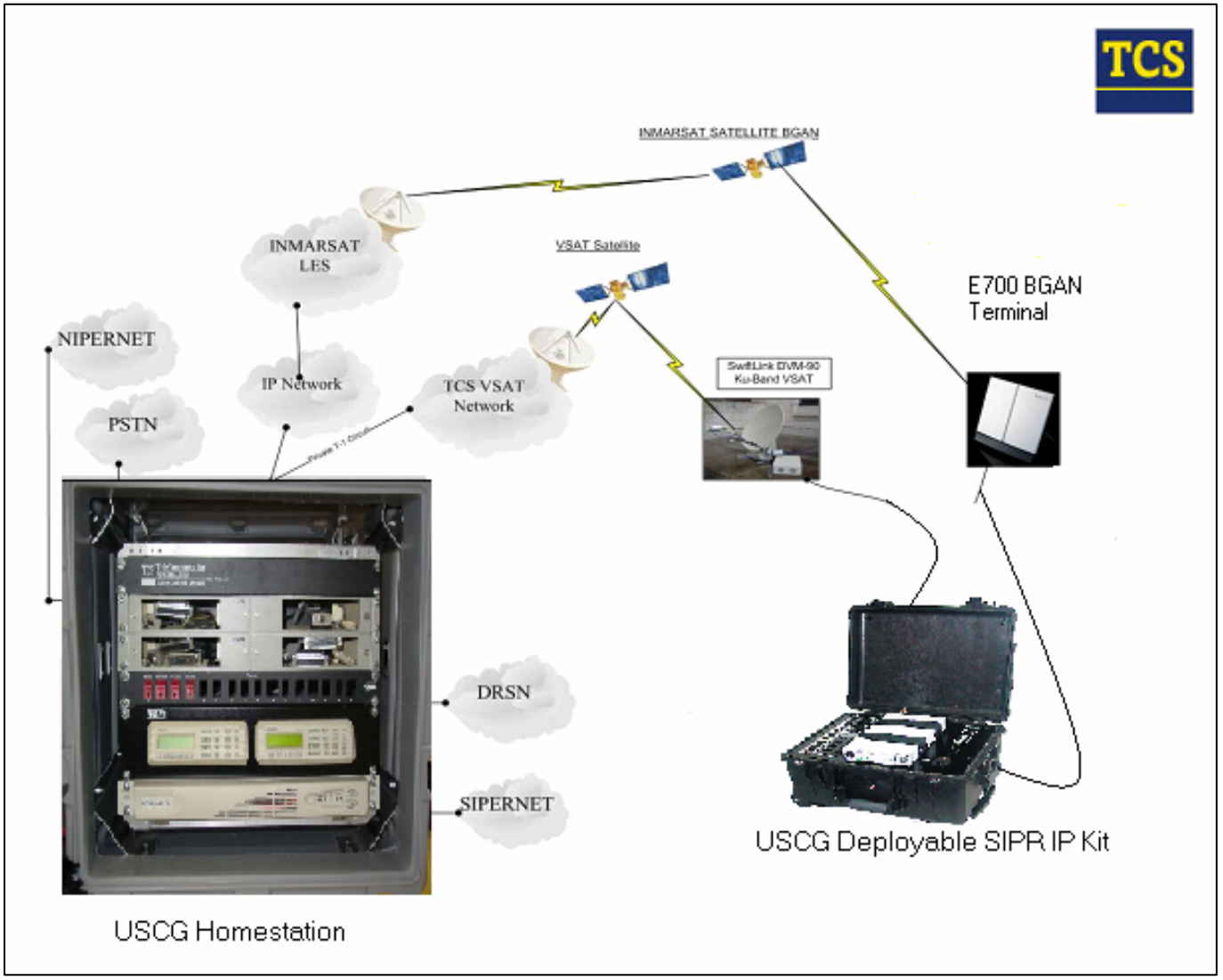
- **Expeditionary Command and Control Suite**

- **What does it do?**
  - Establishes secure voice and data communications via satellite from remote locations
  - Enroute / early-entry
  - Small footprint
  - High bandwidth (capable of 512 kbps or higher)

- **Program Details**
  - Marine Corps program, ACAT IV(T)
  - AoA required for pending Milestone B decision

AoA Alternatives

Alternative A: SwiftLink USCG System



- Designed and integrated by TeleCommunication Systems, Inc. for USCG
- Procurement decision by USCG in April 2006.
- Similar to Alternative C (Dataline's DCD-MN system)
- Ku, BGAN, public Internet

AoA Alternatives

Alternative B: PM WIN-T SECOMP-I System

- Secure Enroute Communications Package, Improved. Upgrade of previous system.
- Managed by PM WIN-T at Ft. Monmouth, NJ. MS C in 4Q FY06.
- Current FFP IDIQ contract with General Dynamics
- Designed primarily for use on aircraft
- Limited to UHF TACSAT (up to 56 kbps) and INMARSAT M4 (64 kbps per channel)

AoA Alternatives

Alternative C: DCD-MN

- Data Communications Device, Multi-Network
- Developed and integrated by Dataline, Inc.
- Similar to Alternative A (SwiftLink USCG System
- Ku, BGAN, public Internet

Objectives

- **Estimate bandwidth costs (O&MMC) for each AoA alternative**
  - SwiftLink, TeleCommunication Systems, Inc. (TCS)
  - SECOMP-I, PM WIN-T, Ft. Monmouth
  - DCD-MN, Dataline, Inc.
- **Estimate should be adjusted for risk**
- **Provide recommendation to decision makers on how much to budget each year for bandwidth.**

These objectives are very vague!

TECOLOTE RESEARCH, INC.
Bridging Engineering and Economics
Since 1973

Conduct the Analysis

Analysis Steps

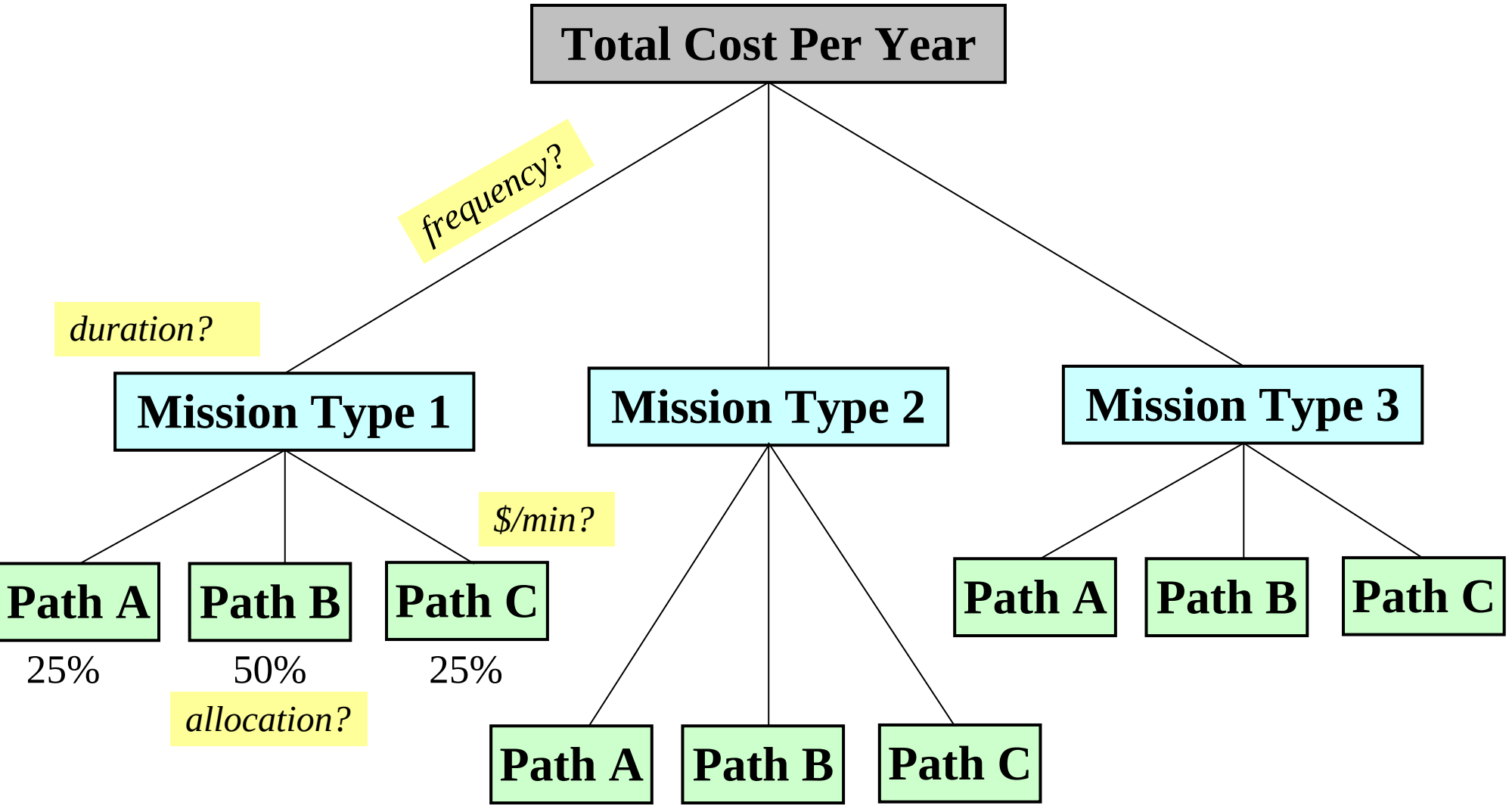
- **Step 1. Collect data**
- **Step 2. Build point estimate**
- **Step 3. Build risk distributions**
- **Step 4. Specify correlation**
- **Step 5. Run the simulation**

Step 1. Collect data

Data collection framework

Questions to consider	Variables
How is the system employed operationally?	*Mission type*
How long does each mission last?	*Mission duration*
How often does each mission occur?	*Mission frequency*
What communication pathways are available in each alternative?	*Communication pathway*
What is the cost of various kinds of satellite bandwidth?	*Bandwidth cost per unit time*
For each alternative, how will air time be allocated among the different communication pathways?	*Bandwidth allocation*

Data collection framework



Step 1a. Define mission types and mission duration

MISSION TYPE	DURATION	DESCRIPTION
Advance Party Operations (APO)	Low: 1 day	This support could be anything from a site survey for an exercise in a remote area to the initial survey and assessment of operational/logistics requirements for a much larger scale operation. The survey or advance party team could be 2-20 personnel providing operational, intelligence, logistics, and communications assessments. The team could operate independent of any existing infrastructure (buildings, power, etc.), or operate out of a hotel.
	Med: 3 days	
	High: 4 days	
Support for Forward Deployed Operations (FDO)	Low: 3 day	This communications requirement would support an assessment team or operations detached from a deployed command. Examples might include a humanitarian relief assessment, Non-combatant Evacuation Operations (NEO), or detachment of personnel to support an on-going operation. Requirements for split operations from deployed Component Command, Marine Expeditionary Unit (MEU), Marine Expeditionary Brigade (MEB) and/or Marine Expeditionary Force (MEF) operations could use the ECCS capabilities to provide operations support to remote areas for early entry or limited duration operations. The ECCS capability is ideally suited for planning support of Marine Operators for deployed exercises and/or advance force operations.
	Med: 7 days	
	High: 14 days	

Step 1a. Define mission types and mission duration

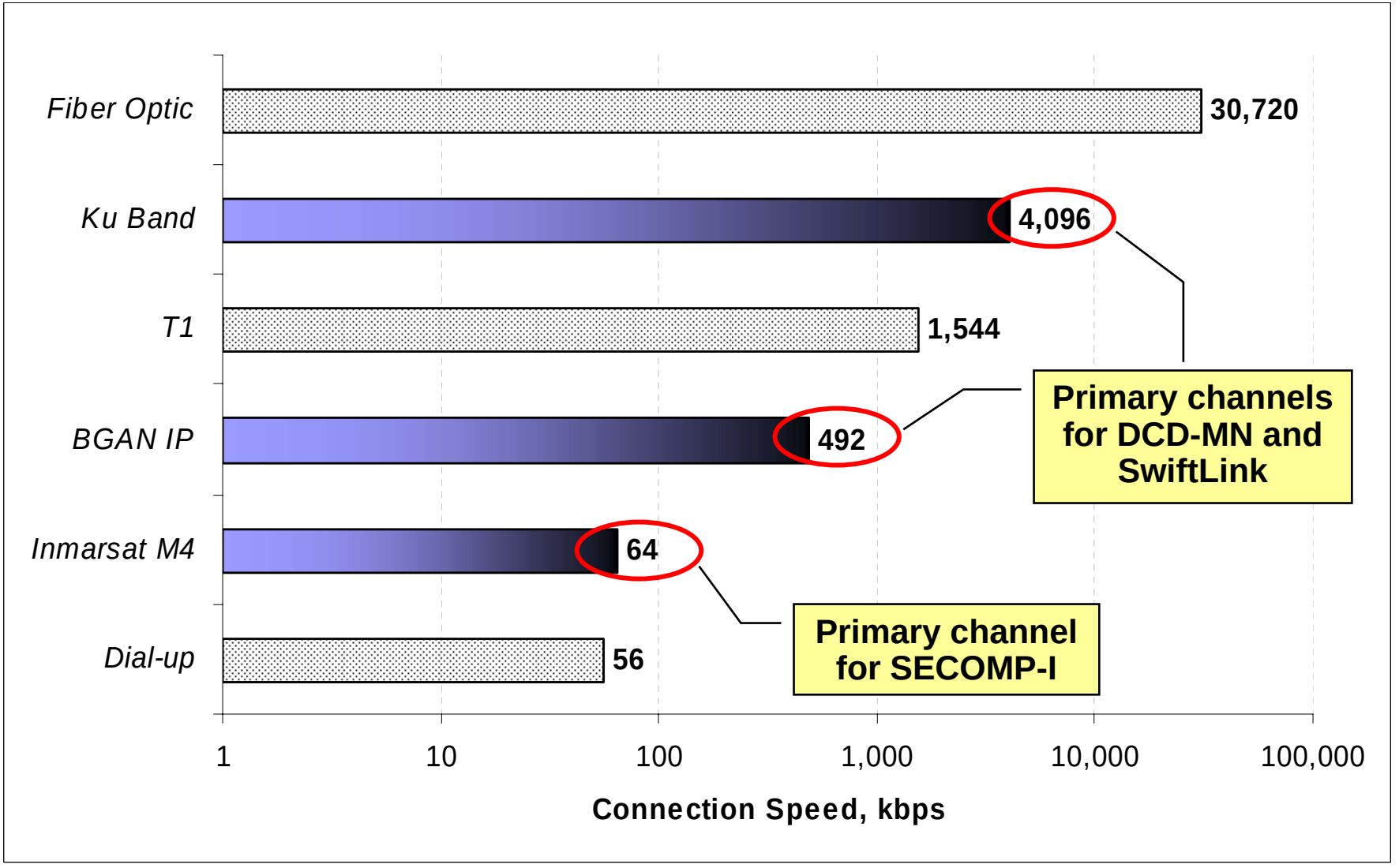
MISSION TYPE	DURATION	DESCRIPTION
Emergency Relief / Aid Missions (ERM)	Low: 14 days	This communications requirement would support an assessment team with operations detached from a parent command (MEF) for up to 30 days. Examples would include humanitarian relief operations such as Hurricane Katrina/Rita or Tsunami relief efforts.
	Med: 21 days	
	High: 30 days	
First Force Communications (FFC)	Low: 3 day	This communications requirement would support an early assessment team with follow on operations for a JTF/Component operation of longer standing duration. Any one of a number of scenarios might dictate this support which would be characterized by perhaps ISP, INMARSAT and/or BGAN support initially and followed by Ku-Band support, if/as required, for longer duration. This scenario would build from the preceding scenarios wherein ECCS provides both early entry (until other communications capabilities are provided) and possibly support to operations within the theater. Component, MEU, MEB and/or MEF commands could use the ECCS capabilities to provide operations support to remote areas for early entry as well as detached operations.
	Med: 7 days	
	High: 14 days	

Step 1b. Define mission frequency

mission type	annual frequency		
	low	**mid**	**high**
advance party ops	10	12	15
supt for fwd deployed ops	18	20	23
emergency relief / aid missions	5	7	10
first force communications	15	17	20

Step 1. Collect data

- **Step 1c. Identify bandwidth data to be collected.**



Step 2. Build point estimate

- **Allocate bandwidth usage to each alternative**

		Hardware		
		DCD-MN	SwiftLink	SECOMP-I
Communication Path	M4 (2 x 64kbps)	–	–	90%
	BGAN Streaming (256 kbps)	20%	20%	–
	BGAN IP (up to 492 kbps)	20%	20%	–
	DSTS-G (9MHz)	10%	10%	–
	On-Demand Ku (512 kbps)	40%	40%	–
	Local ISP (T1)	10%	10%	10%
	Total	100%	100%	100%

Step 3. Build risk distributions

- **Mission Duration and Frequency**
  - **Triangular distributions based on SME opinion**
    - **Low value = lower bound (15% CL)**
    - **Middle value = mode**
    - **High value = upper bound (85% CL)**

- **Bandwidth Rates**
  - Triangular distributions based on actual data collected.
  - Subjective risk distribution applied to on-demand Ku-band cost.

Step 3. Build risk distributions

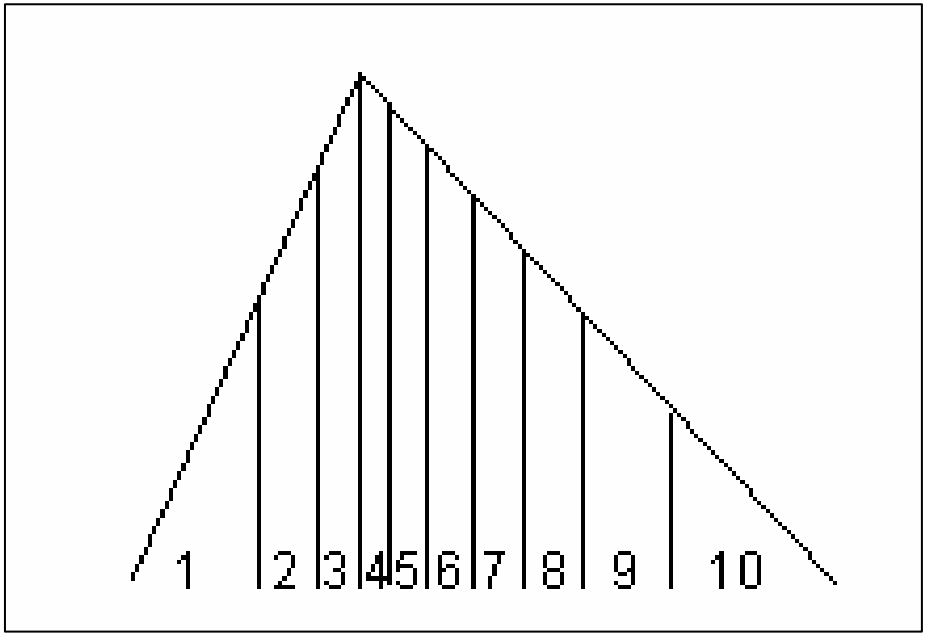
- **Bandwidth Allocation**
  - No risk applied.
  - Use sensitivity analysis to look at discrete cases.

Step 4. Apply correlation

- **Worked with SMEs to generate subjective assessment of correlation**
- **Specified correlation on inputs only**
- **Inputs separated into logical groups**
  - cost per minute
  - duration
  - frequency

Step 5. Run simulation

- **Latin Hypercube sampling method with 10,000 iterations.**



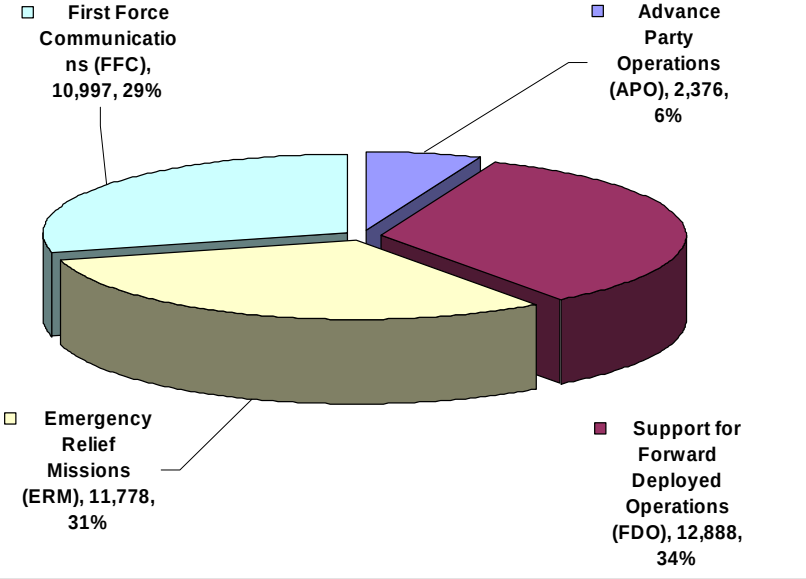
Presented at the 2007 ISPA/SCEA Joint Annual International Conference and Workshop - www.iceaaonline.com

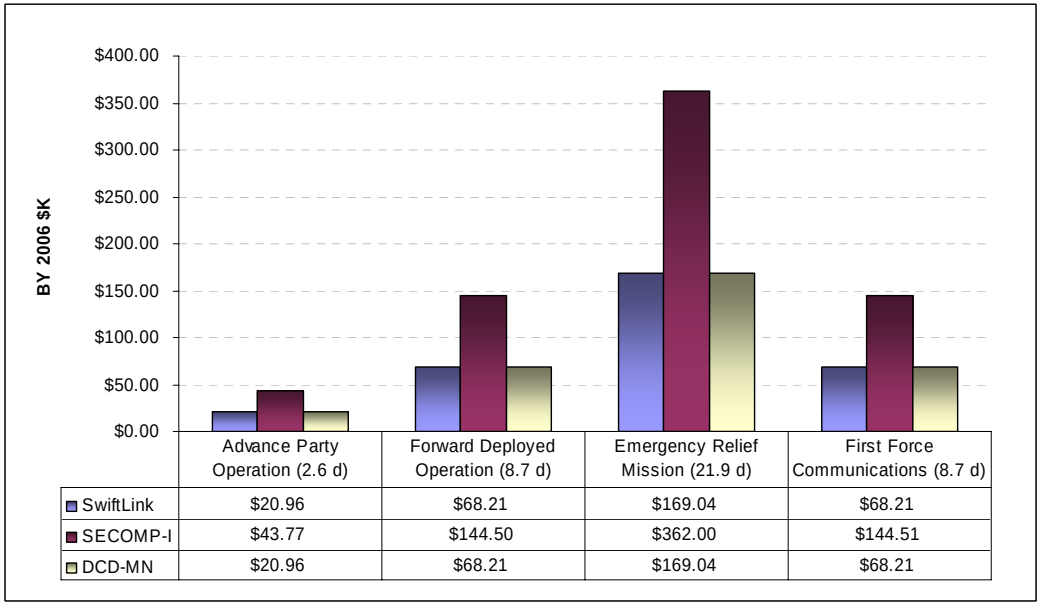
TECOLOTE RESEARCH, INC.
Bridging Engineering and Economics
Since 1973

View and Interpret Results

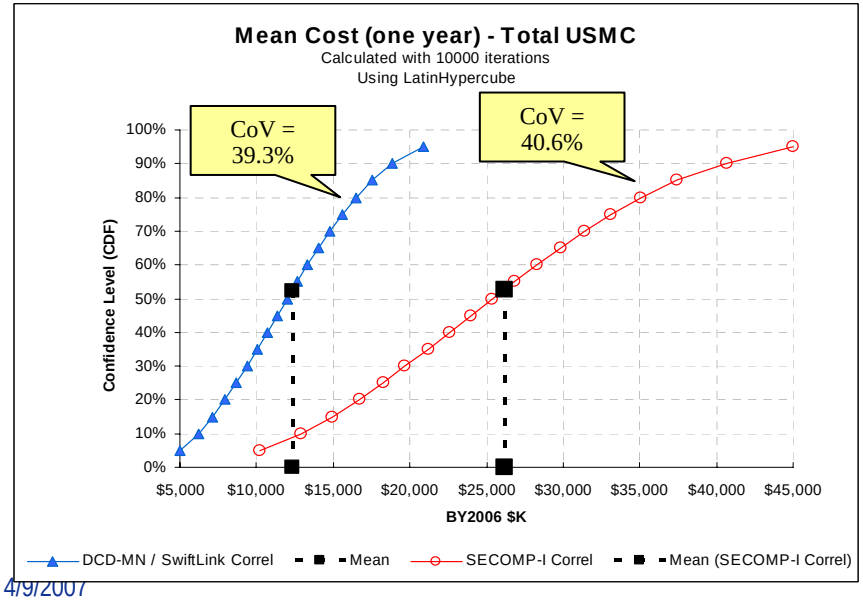
TECOLOTE RESEARCH, INC.
Bridging Engineering and Economics Since 1973

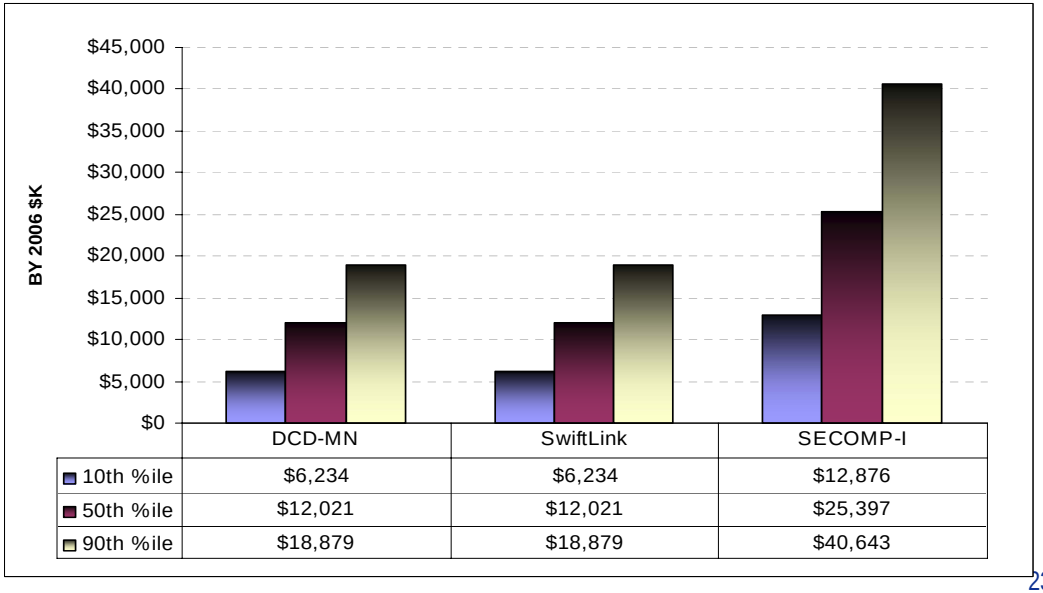
View and Interpret Results





	Advance Party Operation (2.6 d)	Forward Deployed Operation (8.7 d)	Emergency Relief Mission (21.9 d)	First Force Communications (8.7 d)
SwiftLink	$20.96	$68.21	$169.04	$68.21
SECOMP-I	$43.77	$144.50	$362.00	$144.51
DCD-MN	$20.96	$68.21	$169.04	$68.21





	DCD-MN	SwiftLink	SECOMP-I
10th %ile	$6,234	$6,234	$12,876
50th %ile	$12,021	$12,021	$25,397
90th %ile	$18,879	$18,879	$40,643

TECOLOTE RESEARCH, INC.
Bridging Engineering and Economics
Since 1973

Concluding Observations

Conclusions

- **Bandwidth costs for SECOMP-I will approximately double that of SwiftLink and DCD-MN.**
- **Decision makers should closely examine assumptions in this study before choosing an O&M funding level.**

Tecolote Research, Inc.

Bridging Engineering and Economics
Since 1973

Santa Barbara ▮ Los Angeles ▮ Boston ▮ Washington, D.C. ▮ Chantilly ▮ Huntsville ▮ Dayton ▮ Albuquerque
▮ Montgomery ▮ Ogden ▮ Cleveland ▮ San Diego ▮ Colorado Springs ▮ Vandenberg AFB ▮ Denver
▮ Silver Springs ▮ Tacoma ▮ Oklahoma City ▮ San Antonio ▮ New Orleans ▮ Patuxent River

Presented at the 2007 ISPA/SCEA Joint Annual International Conference and Workshop - www.iceaaonline.com

TECOLOTE RESEARCH, INC.
Bridging Engineering and Economics
Since 1973

Backup Slides

References

- **Interpreting upper and lower bounds**
  - The Difficulty in Assessing Uncertainty, Capen, EC, Society of Petroleum Engineers Conference, Dallas TX, 1975
  - Improving Cost Risk Analyses, Biery, Fred, David Hudak, and Shishu Gupta, Journal of Cost Analysis, pp. 57-85, Spring 1994.
- **Satellite link budgets**
  - Larson, Wiley J. and James R. Wertz, eds. 1992. *Space Mission Analysis and Design. Torrance, Calif.: Microcosm, Inc.*
- **General cost-analysis reference**
  - Smith, Alfred, Jeff McDowell, Shu-Ping Hu, Lew Fichter, Tecolote Research. “Air Force Cost Analysis Agency Cost Risk Handbook.” Summer 2007 (expected).

Step 1. Collect data

- **INMARSAT M4 (GAN) – 64 kbps**
  - Intelsat GSA Schedule
  - SATCOM GSA Price Catalog
  - MJ Sales, Inc.
- **INMARSAT BGAN (background IP and streaming)**
  - Telenor GSA Schedule
  - SATWEST BGAN Airtime Pricing
  - Outfitter Satellite, Inc. BGAN Rates
  - GMPCS BGAN Airtime Rates

Step 1. Collect data

- **DISA DSTS-G Commercial Ku-band**
  - Arrowhead Global Solutions, Inc.
  - Hourly, daily, weekly, monthly, yearly rates
  - 36, 18, 9, 1 MHz
  - Minimum 9 MHz required for 512 kbps download speed

- **On-Demand Ku-band**
  - Segovia (Bob Otten, Dataline)
  - immixGroup GSA Schedule
  - Sprint GSA Schedule
  - TeleCommunication Systems, Inc. GSA Schedule

Step 2. Build point estimate

M4 (GAN) - 64 kbps	$/Min
Intelsat	6.34
SATCOM	5.75
MJ Sales, Inc.	6.96
Mean	**6.35**

Up to 492 kbps

BGAN / Background IP	$/Min
Telenor	6.89
SATWEST	5.93
Outfitter Satellite, Inc.	6.95
GMPCS	6.50
Mean	**6.57**

BGAN / 256 kbps streaming	$/Min
Telenor	18.39
SATWEST	18.05
Outfitter Satellite, Inc.	19.90
GMPCS	18.07
Mean	**18.60**

Step 2. Build point estimate

DISA DSTS-G

9 MHz Ku-band	Mean $
Yearly	543,426
Monthly	56,088
Weekly	18,424
Daily	3,256
Hourly	1,085

On Demand Ku-band

Cost for 24/7 service *512 kbps/512kbps*	**Cost (FY06 $)**
1 day	$460.07 / day
2 weeks	$5,367.50
1-3 months	$5,367.50 / month

TECOLOTE RESEARCH, INC.
Bridging Engineering and Economics Since 1973

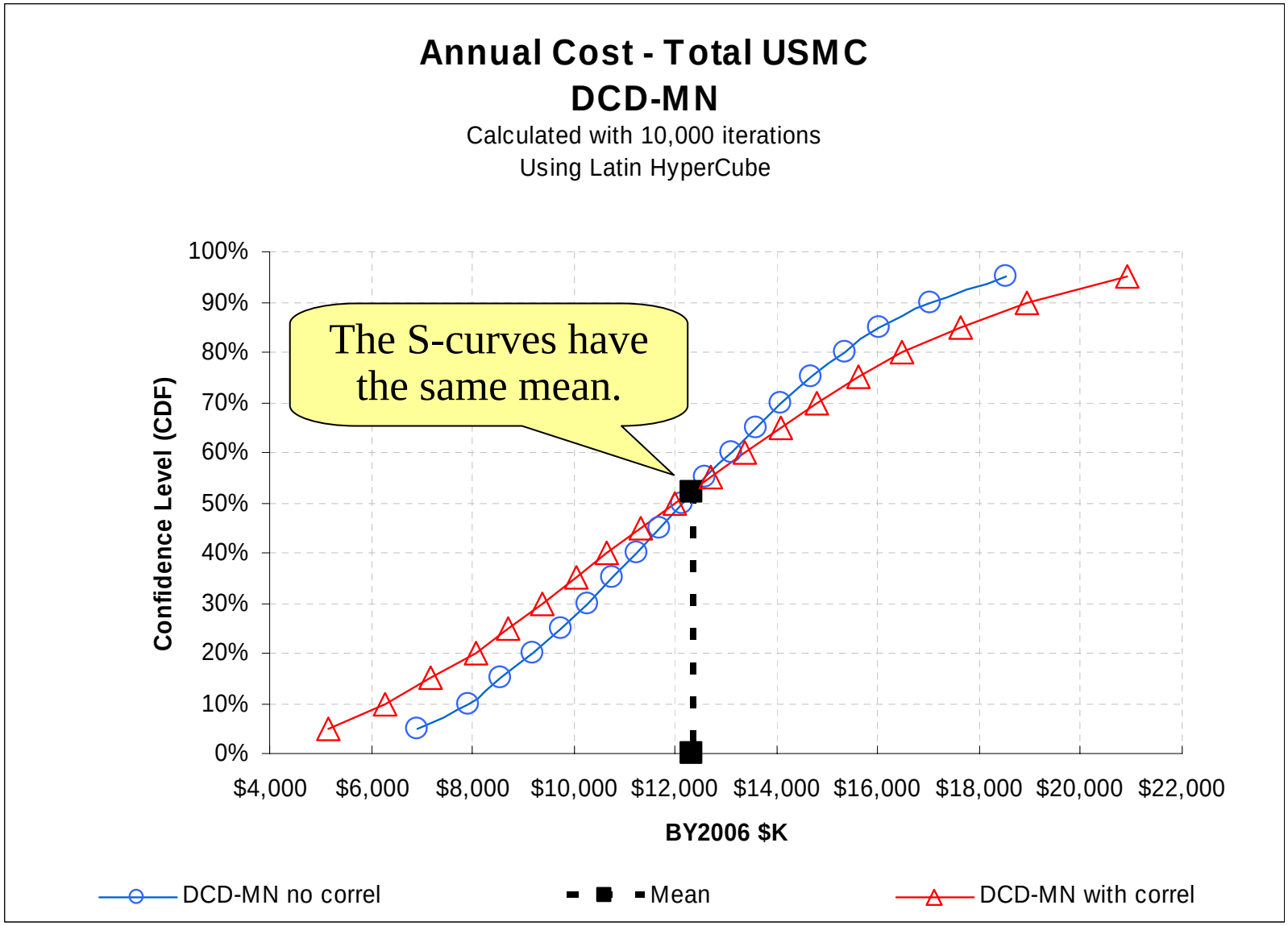
Step 4. Apply correlation

- **Step 4b. Specify additional correlation as required.**

Correlation Group	Cor. Strength
BGAN	
BGAN - 32 kbps Streaming (Cost Per Min)	0.9
BGAN - 64 kbps Streaming (Cost Per Min)	0.9
BGAN - 128kbps Streaming (Cost Per Min)	0.9
BGAN - 256 kbps Streaming (Cost Per Min)	0.9
BGAN - Background IP (Cost Per Min)	0.9
DSTS-G Ku	
Ku Band - Mean (Cost Per Year)	0.9
Ku Band - Mean (Cost Per Monthly)	0.9
Ku Band - Mean (Cost Per Weekly)	0.9
Ku Band - Mean (Cost Per Daily)	0.9
Ku Band - Mean (Cost Per Hourly)	0.9
On Demand Ku	
512kbps / 512kbps (Cost Per Month - 24/7)	0.9
1024kbps / 512kbps (Cost Per Week - 8 hr. Day)	0.9
512kbps / 512kbps (Cost Per Week - 4 hr. Day)	0.9
512 kbps / 512 kbps (Cost Per Day - 24 hr. Day)	0.9

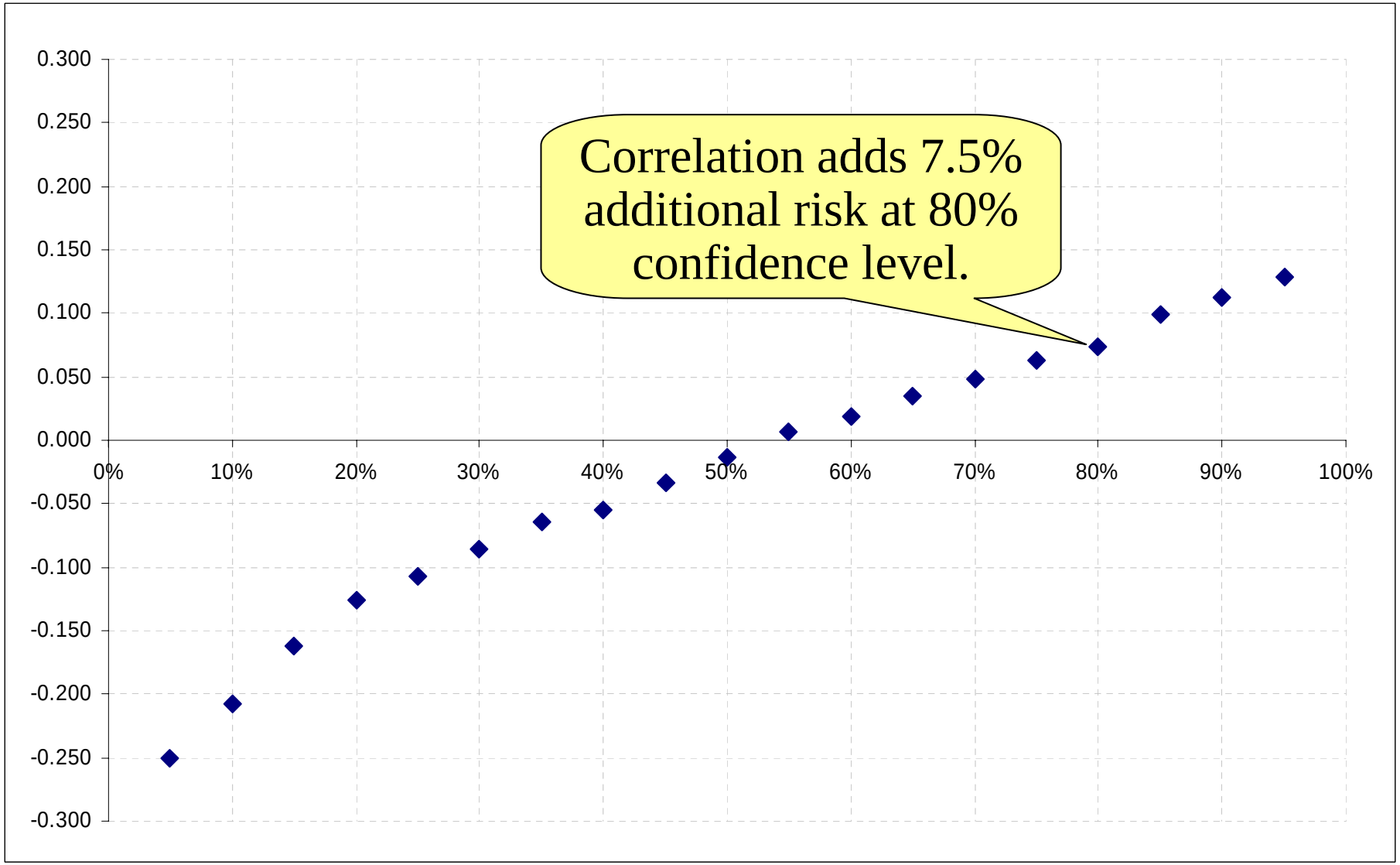
Correlation Group	Cor. Strength
Mission Duration	
Advance Party Operations (APO)	0.9
Support for Forward Deployed Operations (FDO)	0.9
Emergency Relief/Aid Missions (ER)	
First Force Communications (FFC)	0.9
Mission Frequency	
Advance Party Operations (APO)	0.9
Support for Forward Deployed Operations (FDO)	0.9
Emergency Relief Missions (ERM)	
First Force Communications (FFC)	0.9

Impact of Correlation



Impact of Correlation

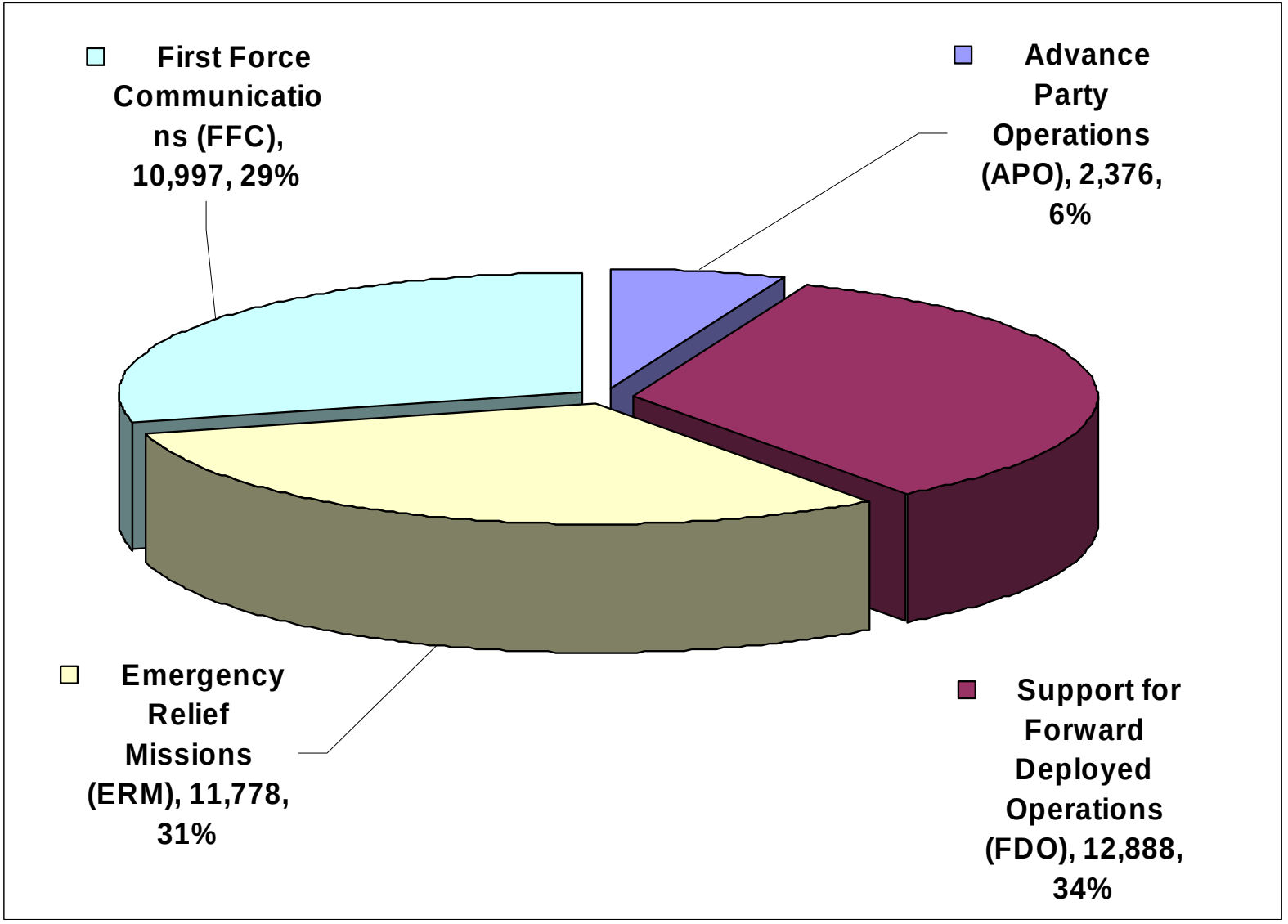
- **Correlated risk, % delta relative to non-correlated risk**



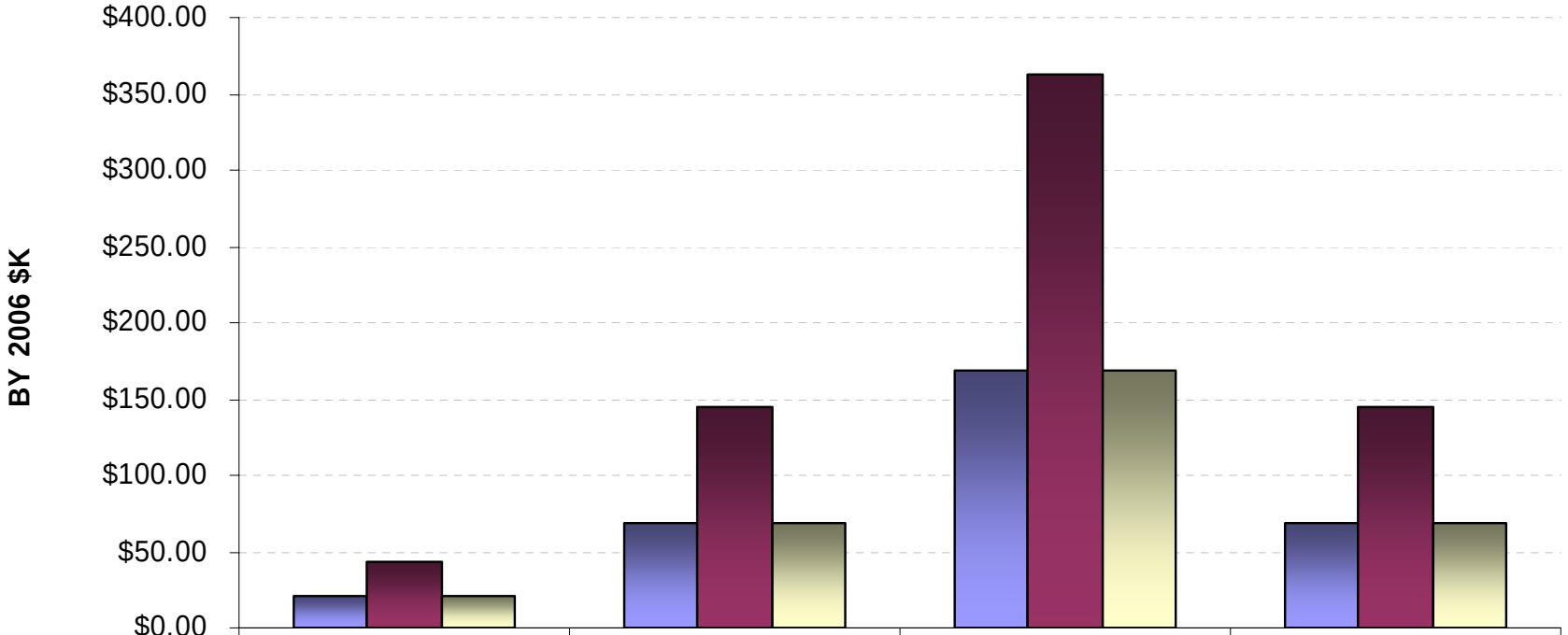
Impact of Correlation

- **Correlation has greatest impact at tails of distribution**
- **Correlation added a moderate amount of cost risk that otherwise would have remained unaccounted for**

Breakdown by mission type (hours/yr)

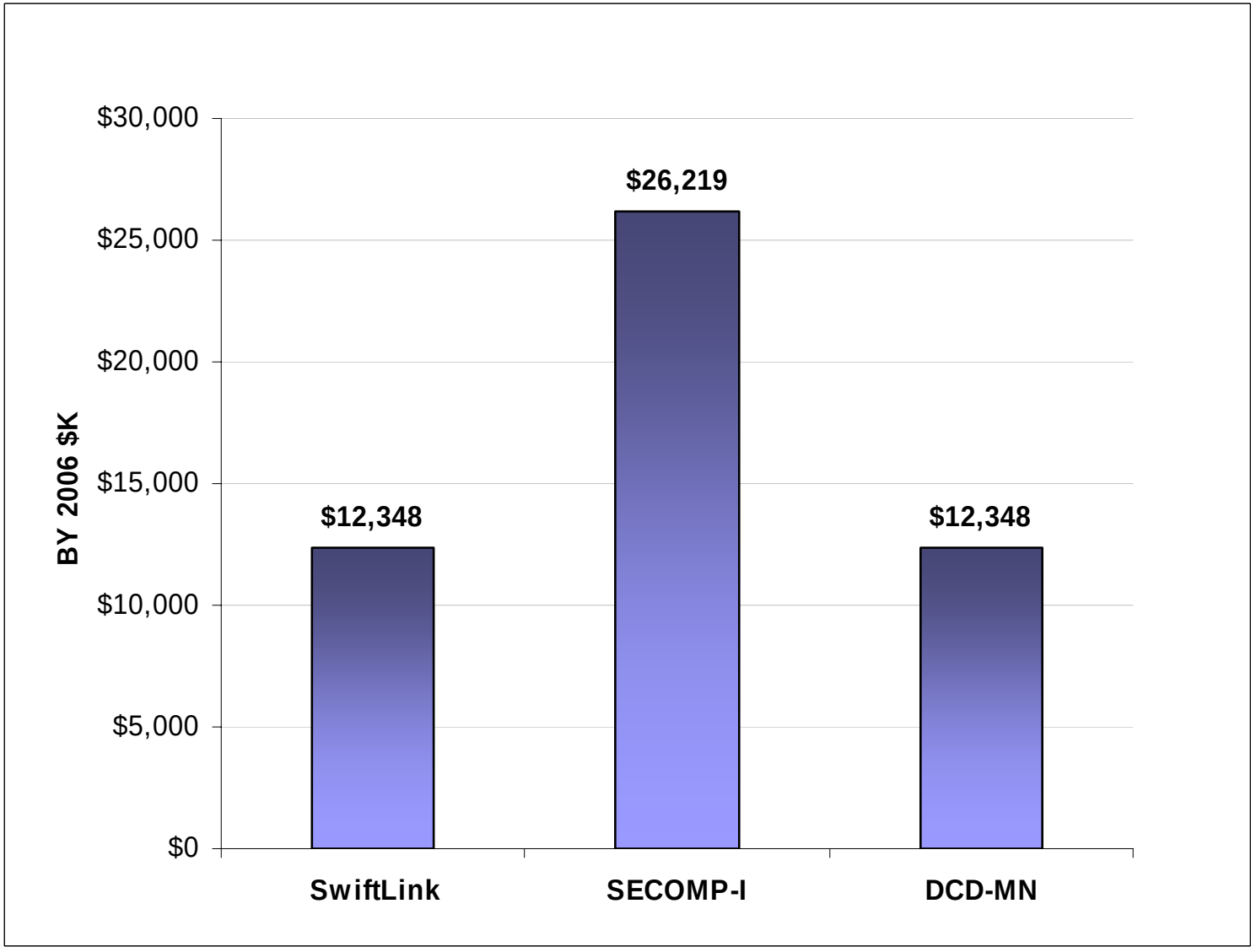


Mean cost per mission

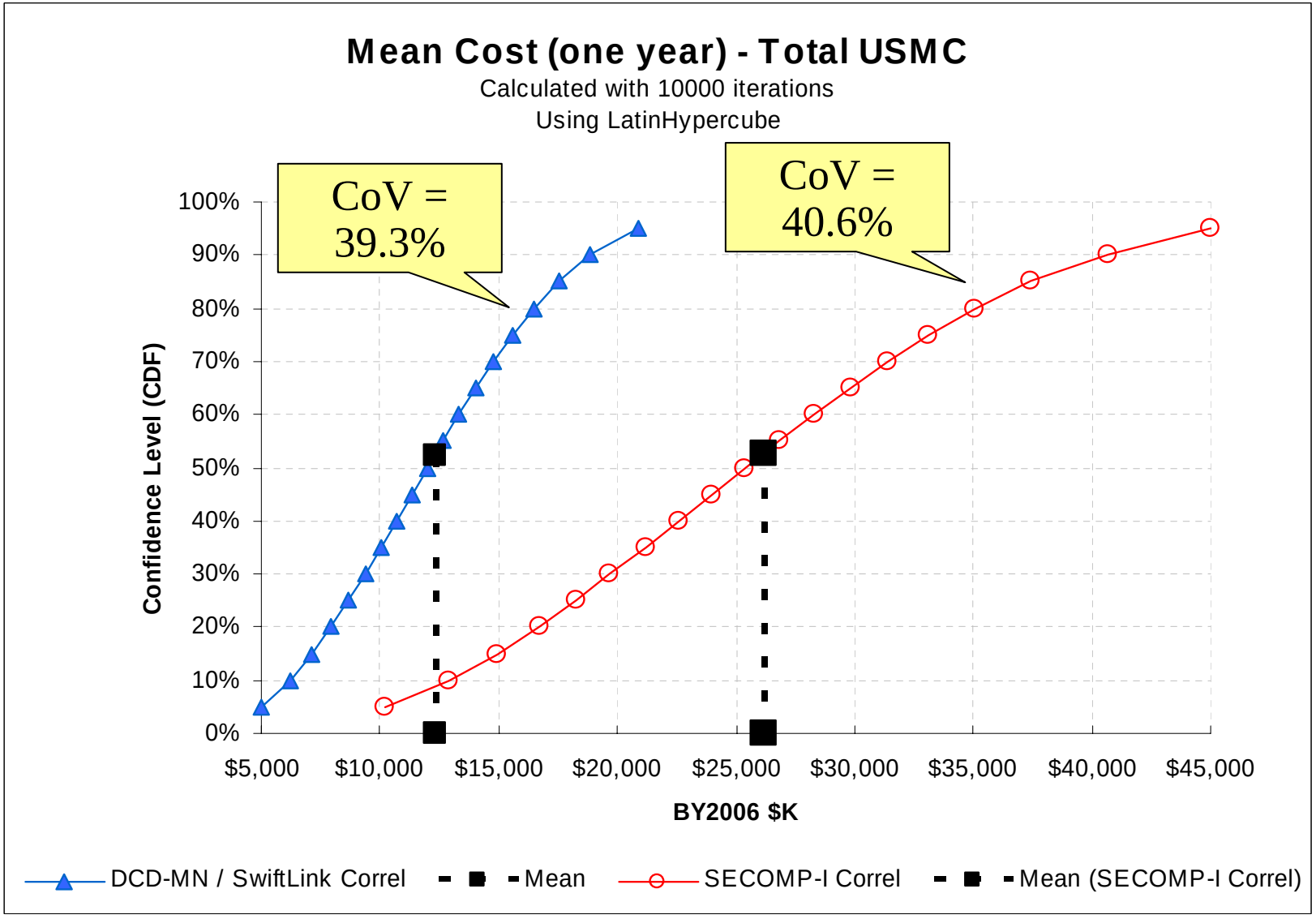


	Advance Party Operation (2.6 d)	Forward Deployed Operation (8.7 d)	Emergency Relief Mission (21.9 d)	First Force Communications (8.7 d)
SwiftLink	$20.96	$68.21	$169.04	$68.21
SECOMP-I	$43.77	$144.50	$362.00	$144.51
DCD-MN	$20.96	$68.21	$169.04	$68.21

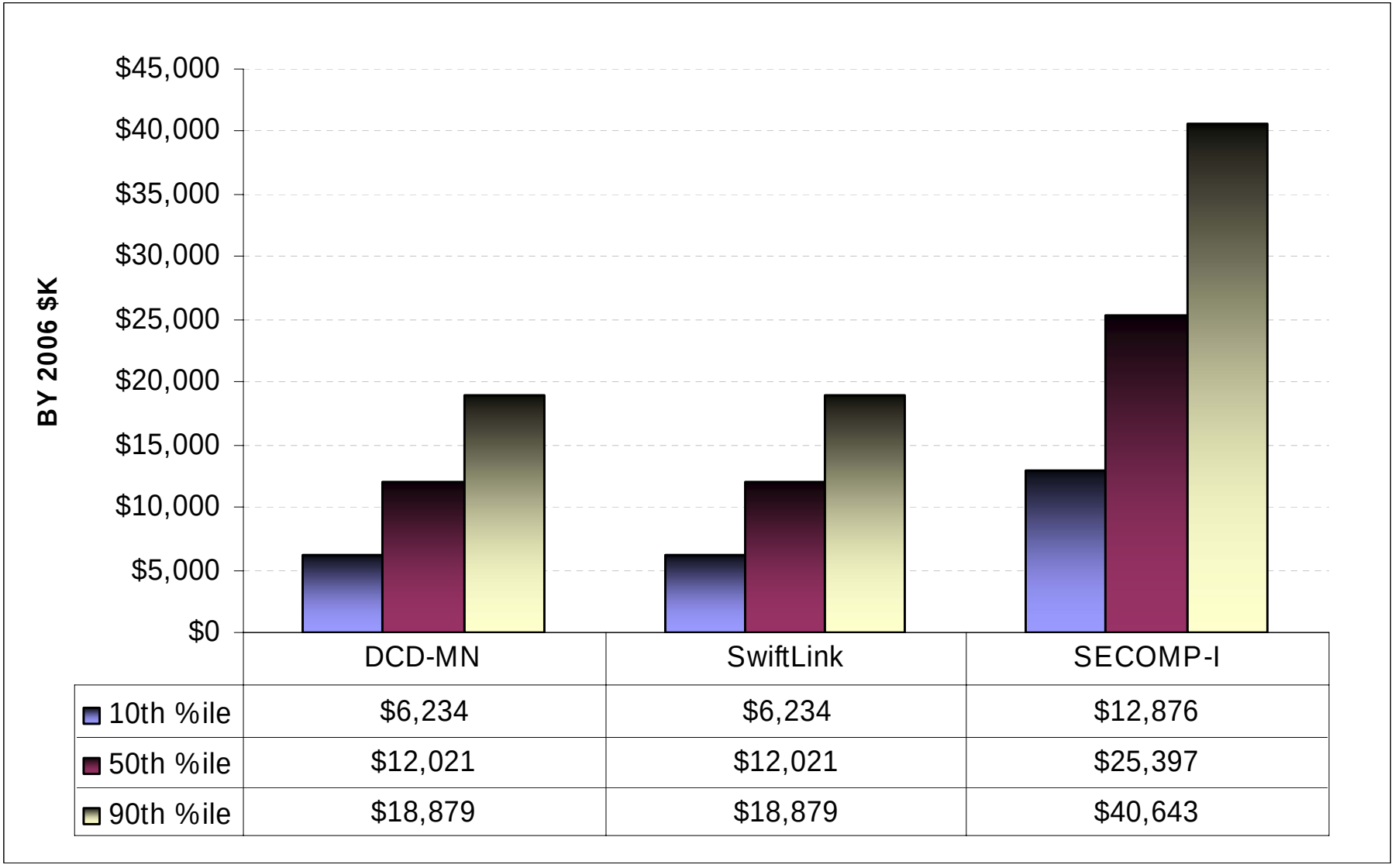
Mean cost per year (Total USMC)



Comparison of alternatives



Comparison of alternatives



	DCD-MN	SwiftLink	SECOMP-I
10th %ile	$6,234	$6,234	$12,876
50th %ile	$12,021	$12,021	$25,397
90th %ile	$18,879	$18,879	$40,643