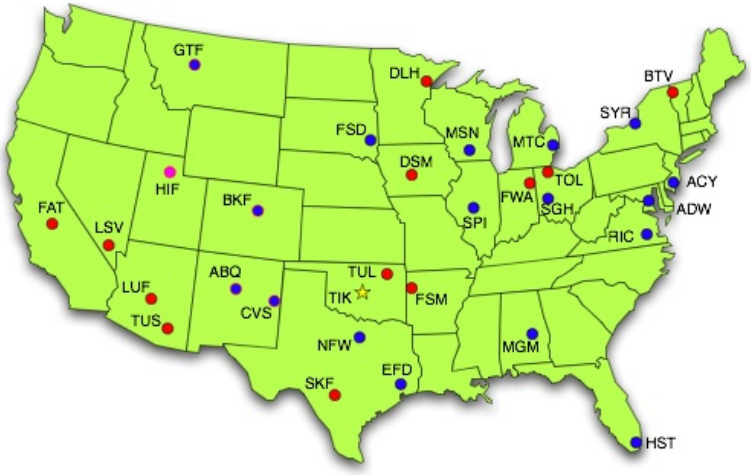
Acquisition Research Program:
Creating Synergy for Informed Change

Open Architecture, Inventory Pooling and Maintenance Modules

Geraldo Ferrer

Associate Professor, Naval Postgraduate School

Location of F-16 CONUS bases



☆ Engine maintenance depot
● Pratt & Whitney base
● General Electric base
● F-16 maintenance depot

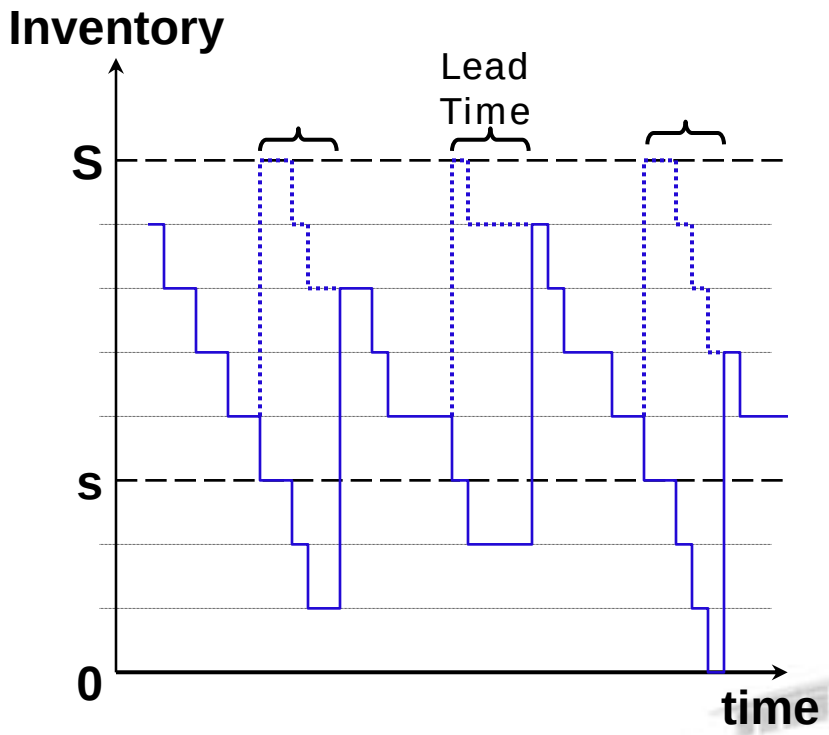
- Each base stores own engines using a base stock policy.
- Policy is defined centrally. Details FOUO.
- Tinker AFB (OK) is engine maintenance depot.
- Hill AFB (UT) is the F-16 aircraft depot.

Forecast demand FY 2008 (sample)

Base	‘01	‘02	‘03	‘04	‘05	‘06	‘07	Fcast	Std Err
DSM	40	37	32	28	12	25	13	8.9	5.7
LSV	88	57	92	90	97	66	60	69.9	17.7
TUL	43	34	21	22	21	18	9	4.9	4.5
ACY	44	53	51	53	38	20	22	19.4	9.5
HIF	245	201	225	236	202	230	220	217.0	17.8
HST	40	31	41	32	34	26	33	28.4	4.7

Distributed inventory policy

- Continuous review.
- Policy for each user defined individually.
- (S,s) policy includes two components:
  - Inventory target level (S)
  - Reorder point level (s)

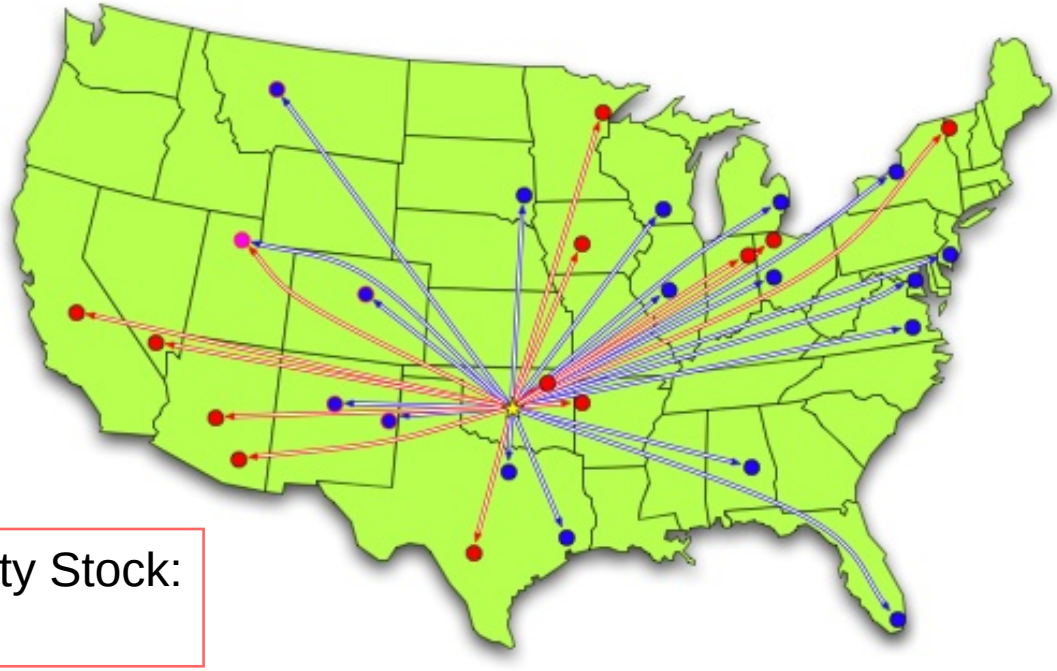


Reorder point = expected demand during lead time + safety stock

Safety stock = f(variability, lead time)

Optimal distributed inventory policy:
Each base stores its own replacement engines using a **(S,s) policy**.

	P&W	GEAE	Total
Annual Demand	656	773	1429
Safety Stock	18	22	40
Base Stock	38	48	86



Cost of Safety Stock:
$123.9M

Pooling approaches to reduce variability in the supply chain

- Time aggregation
  - There is **less variability in longer time** periods than in short periods.
- Place aggregation
  - There is **less variability in the aggregate demand of a larger group of customers** than in the demand of a single one.
- Product aggregation
  - There is **less variability in the aggregate demand of several products** than in the demand of a single one.

Regional inventory

Open Architecture

Place aggregation:

$$\mu_{X+Y+\ldots+Z} = \mu_X + \mu_Y + \ldots + \mu_Z$$

$$\sigma_{X+Y+\ldots+Z} = \sqrt{\sigma_X^2 + \sigma_Y^2 + \ldots + \sigma_Z^2}$$

Let Safety Stock be equal to 2 times std deviation:

Customer	Demand	Safety Stock
Andrews AFB DC	N(100,40)	80
Hill AFB UT	N(100,40)	80
Cannon AFB NM	N(50,20)	40
National Demand	N(??,??)	??

Place aggregation:

$$\mu_{X+Y+\ldots+Z} = \mu_X + \mu_Y + \ldots + \mu_Z$$

$$\sigma_{X+Y+\ldots+Z} = \sqrt{\sigma_X^2 + \sigma_Y^2 + \ldots + \sigma_Z^2}$$

Let Safety Stock be equal to 2 times std deviation:

Customer	Demand	Safety Stock
Andrews AFB DC	N(100,40)	80
Hill AFB UT	N(100,40)	80
Cannon AFB NM	N(50,20)	40
National Demand	N(250,60)	120

Safety stock is reduced by 40%

Regional inventory policy

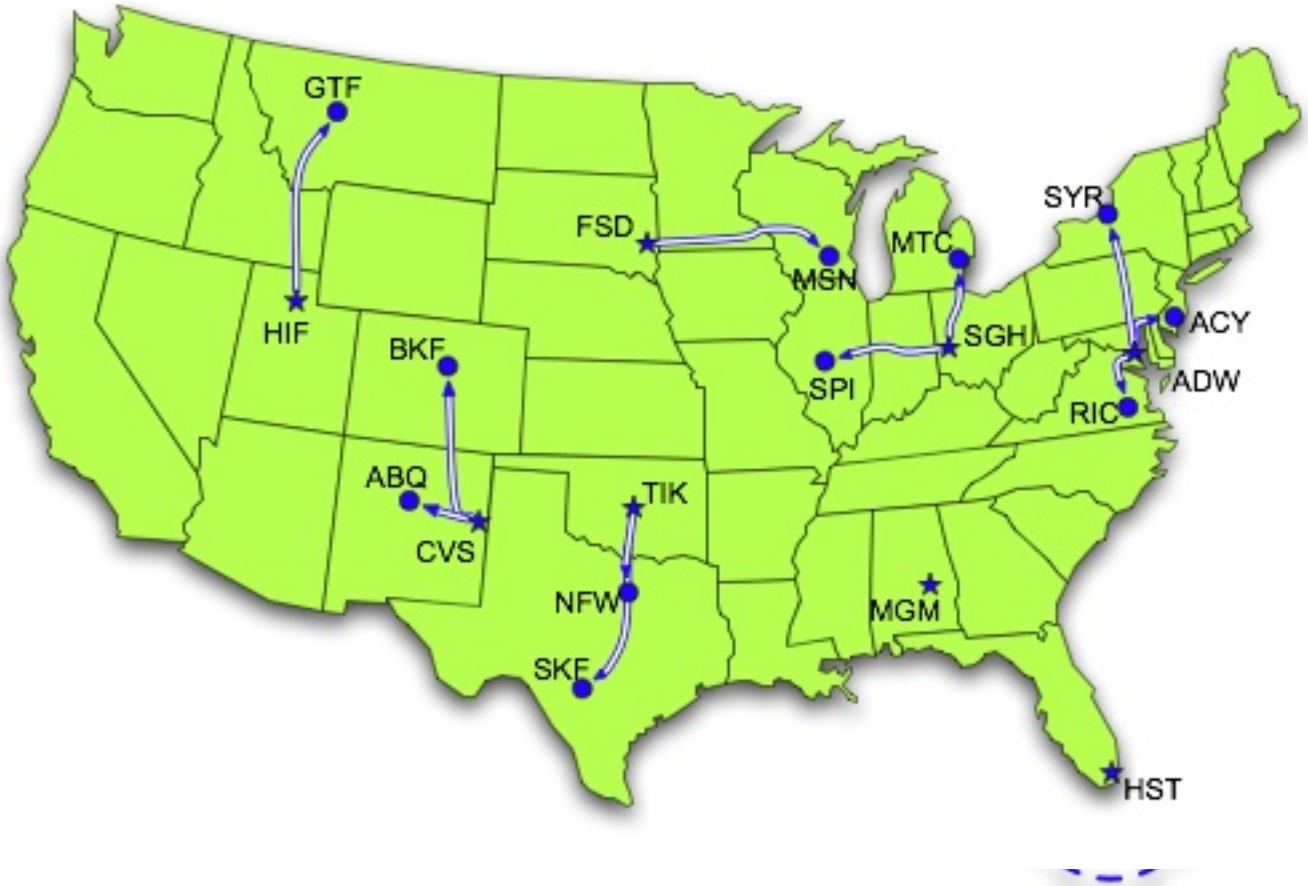
- All bases must be within one-day drive from source.
- Source must hold inventory to meet demand of all bases in cluster.
- Selection of source is based on:
  - Distance to other bases
  - Demand in source and neighboring bases
  - Subjective handicap
    - Depot (Tinker) > active duty > national guard or reserve

Selection of Pratt & Whitney bases using the Ardalan heuristic

Selection of Pratt & Whitney bases using the Ardalan heuristic

Lowest cost location	Selected distribution sites	Users within range
LUF	LUF	4
TIK	LUF, TIK	8
BTV	LUF, TIK, BTV	9
HIF	LUF, TIK, BTV, HIF	10
DLH (LSV)	LUF, TIK, BTV, HIF, DLH	11
FWA (LSV)	LUF, TIK, BTV, HIF, DLH, FWA	13 (all)

Selection of General Electric bases using the Ardalan heuristic



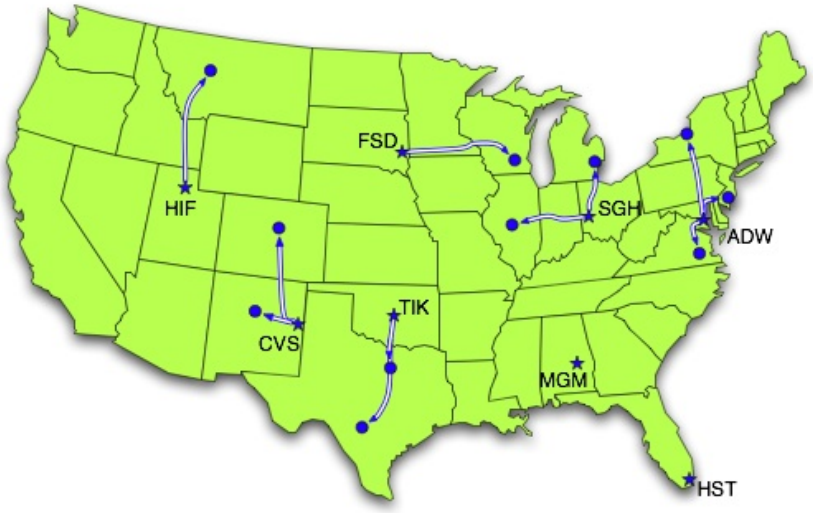
Selection of General Electric bases using the Ardalan heuristic

Lowest cost location	Selected distribution sites	Users within range
TIK	TIK	4
HIF	TIK, HIF	6
ADW	TIK, HIF, ADW	12
SGH	TIK, HIF, ADW, SGH	14
HST	TIK, HIF, ADW, SGH, HST	15
MGM	TIK, HIF, ADW, SGH, HST, MGM	16
CVS	TIK, HIF, ADW, SGH, HST, MGM, CVS	17
FSD	TIK, HIF, ADW, SGH, HST, MGM, CVS, FSD	18 (all)

Optimal regional inventory policy:

Selected bases store the inventory for all bases within a region.
Bases selected according to **Ardalan heuristic**.

	P&W	GEAE	Total
# of Storage Bases	6	8	12
Annual Demand	657	772	1429
Safety Stock	11	15	26
Base Stock	29	37	66



Cost of Safety Stock:
$80.3M (*35% savings*)

Open architecture

- Combines the benefits of commonality and modularity in product design:
  - If two suppliers design a component with same functionality, both must adopt the same interface with the main product.
  - Internal design may be different.

  - Usually adopted in software design.
  - May also be adopted in physical products.

Block 30 F110-GE

Block 32 F100-PW

Source: http://www.habu2.net/vipers/viperblocks/

Product aggregation:

$$\mu_{X+Y+\ldots+Z} = \mu_X + \mu_Y + \ldots + \mu_Z$$

$$\sigma_{X+Y+\ldots+Z} = \sqrt{\sigma_X^2 + \sigma_Y^2 + \ldots + \sigma_Z^2}$$

Let Safety Stock be equal to 2 times std deviation:

Product	Demand	Safety Stock
F100 P&W F110 GEAE	N(80,30) N(120,40)	60 80
National Demand	N(200,50)	100

Safety stock is reduced by 28%

Hence:

- **Product aggregation** (through Open Architecture) may provide the same demand pooling benefit as **Place aggregation**!

- Even **greater benefit** can be obtained when both types of aggregations are exercised.

Regional inventory with Open Architecture benefit

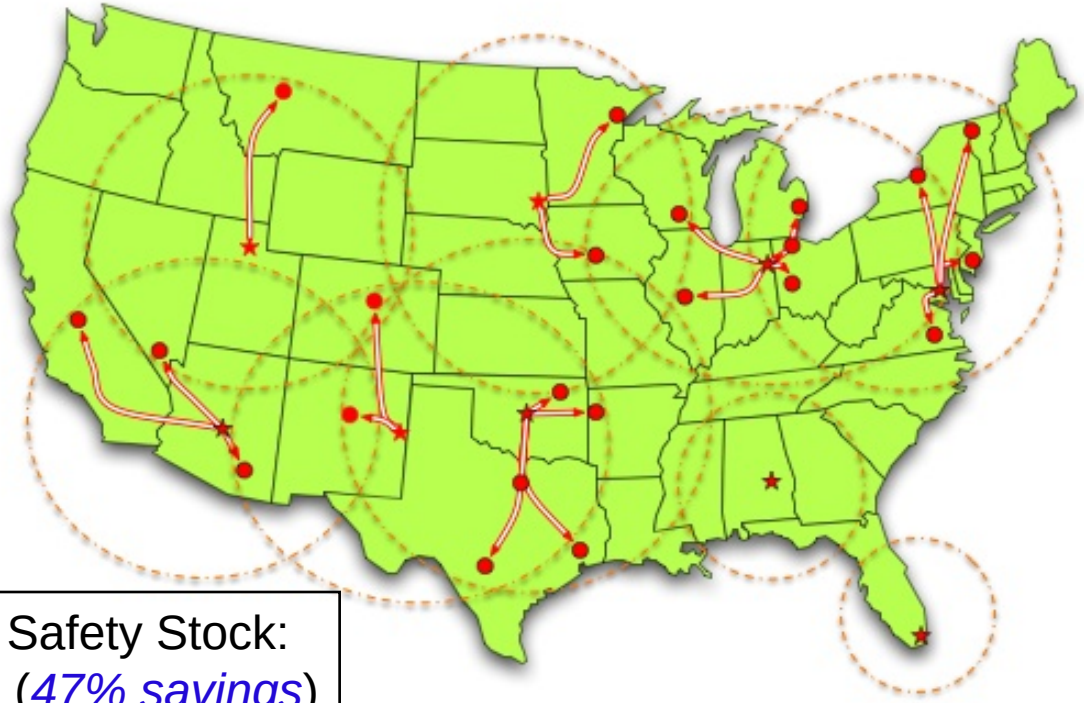
- Same requirements as before, plus…
- … all aircraft may receive engines from either manufacturer.

- *This requirement is in the JSF specifications.*

Both manufacturers are expected to adopt the same hardware and software interface with the airframe.

Optimal inventory policy with open architecture benefit:
Sources found using the **Ardalan heuristic**.

	P&W and GEAE
# Storage Bases	9
Annual Demand	1429
Safety Stock	59
Base Stock	21



Cost of Safety Stock:
$65.1M (*47% savings*)

Selection of bases using OA engines based on the Ardalan heuristic

Lowest cost location	Selected distribution sites	Users within range
ABQ	ABQ	6
ADW	ABQ, ADW	15
HIF	ABQ, ADW, HIF	18
LUF	ABQ, ADW, HIF, LUF	19
TIK	ABQ, ADW, HIF, LUF, TIK	24
FWA	ABQ, ADW, HIF, LUF, TIK, FWA	26
FSD	ABQ, ADW, HIF, LUF, TIK, FWA, FSD	28
HST	ABQ, ADW, HIF, LUF, TIK, FWA, FSD, HST	29
MGM	ABQ, ADW, HIF, LUF, TIK, FWA, FSD, HST, MGM	30 (all)

Summary of results

	Current policy	Regional storage only	Regional storage with OA
# Storage bases	30 + Tinker AFB (depot)	12	9
Cost of safety stock (ideal)	$123.9M	$80.3M	$65.1M
% Transportation increase	n/a	7.1%	10.1%

Important lessons

- Open architecture…
  1. … is an effective means of **product aggregation to facilitate supply-chain improvement** for valuable complex assets.
  2. … can be **leveraged by place aggregation**, when the asset is used by several facilities geographically distributed.
  3. … can provide **substantial benefits by judicious identification of regional cluster of users** to share the joint inventory.
- Reduction in the number of storage points generally increases transportation cost.
  - It is important to evaluate the trade-off between **reduced investment in inventories** against **increased transportation cost**.