Aircraft Operation – Cost Models

Lessons Learned!

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Presentation Purpose

To relate what I learned while participating in initiatives to improve Aircraft O&S cost models:

- Aircraft Operation & Sustainment (Resource Oriented) Cost Model
- Aircraft Cost Per Flying Hour Risk Model
- Jet Engine Maintenance Cost Model

Disclaimer

- **Information presented is representative of cost data and is not actual data.**
- **Information and opinions presented are that of the presenter and do**

Aircraft O&S (Resource Oriented) Cost Model

What Will Be Covered:

- What was the Cost Oriented Resource Estimating (CORE) guideline
    - What was the Aircraft Operation & Sustainment Cost Model WBS
    - What were Aircraft Operation & Sustainment Cost Model Algorithms and Factors
- What is the CORE Template

The CORE

- The CORE was a "giant" MS Word document that described the WBS, methodology and factors for calculating cost elements.
- Separate cost element methodologies were described for each AF division (AD, ANG, AFR) as well as for each MDS.
- For each WBS cost element, methodology factors were identified and described and instructions provided for sourcing and normalizing.
- Changing CONOPS, new platforms and changing design series variations presented significant CORE maintenance challenges.
- Separate estimates for specific platforms were produced each year in ad hoc formats designed by an assigned analyst.
- Pre-release estimate reviews uncovered analyst introduced errors.

The CORE

Unit Mission Personnel
- Operations
  - Aircrew
    - If AD
      - If F16
        - If C Variation
          - Get Pilot/Crew Headcount Factor
            - Go to Table A36-1
              - Locate Cost Factor
                - Read Normalizing Notes
                  - Normalize Factor

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Aircraft O&S (Resource Oriented) Cost Model WBS

1.0 Unit Mission Personnel
1.1 Operations
1.1.1 Aircrew
1.2 Maintenance
1.2.1 Organizational Maintenance
1.2.1.1 Military Pay
1.2.1.2 Civilian Pay
1.2.2 Intermediate Maintenance
1.2.2.1 Military Pay
1.2.2.2 Civilian Pay
1.2.3 Ordnance Maintenance
1.2.3.1 Military Pay
1.2.4 Other Maint Personnel
1.2.4.1 Military Pay
1.2.4.2 Civilian Pay
1.3 Other Mission Personnel
1.3.1 Unit Staff
1.3.1.1 Military Pay
1.3.1.2 Civilian Pay
1.3.2 Security
1.3.2.1 Military Pay
1.3.2.2 Civilian Pay
1.3.3 Other
1.3.3.1 Military Pay
1.3.3.2 Civilian Pay

2.0 Unit Level Consumption
2.1 POL/Energy Consumption
2.1.1 POL
2.1.2 Field Generated Electricity
2.1.3 Commercial Electricity
2.2 Consumable Material/Repair Parts
2.2.1 Maintenance Material
2.2.1.1 Aircraft Maintenance Material
2.2.2 Mission Support Supplies
2.3 Depot Level Reparables
2.4 Training Munitions/Expendable Stores
2.5 Other Unit Level Consumption (ie Non-fly DLR)

3.0 Intermediate Maintenance
3.1 Maintenance
3.1.1 Military Pay
3.1.2 Civilian Pay
3.2 Consumable Material/Repair Parts
3.3 Other Intermediate Maintenance

Aircraft O&S (Resource Oriented) Cost Model WBS

4.0 Depot Maintenance
4.1 Overhaul/Rework
4.1.1 Airframe
4.1.2 Engine Rework
4.1.3 Component Repair (DBOF Exempt)
4.1.4 Support Equipment
4.2 Other Depot
4.2.1 General Depot Support
4.2.2 Second Destination Transportation (over DLR)
4.2.3 Miscellaneous Depot

5.0 Contractor Support
5.1 Interim Contractor Support
5.2 Contractor Logistics Support
5.3 Other Contractor Support

6.0 Sustaining Support
6.1 Support Equipment Replacement
6.2 Modification Kit Procurement/Installation
6.3 Other Recurring Investment
6.4 Sustaining Engineering Support
6.5 Software Maintenance Support
6.6 Simulator Operations
6.7 Other Sustaining Support

7.0 Indirect Support
7.1 Personnel Support
7.1.1 Medical Support
7.1.1.1 Military Pay
7.1.1.2 Civilian Pay
7.1.1.3 Non-Pay/Material
7.1.2 Specialty Training
7.1.2.1 Pilot Training
7.1.2.2 Non-Pilot Aircrew Training
7.1.2.2.1 Officer
7.1.2.2.2 Enlisted
7.1.2.3 Non-Aircrew Training
7.1.2.3.1 Officer
7.1.2.3.2 Enlisted
7.1.2.3.3 Civilian
7.1.3 PCS
7.1.3.1 Officer
7.1.3.2 Enlisted
7.1.3.3 Civilian
7.2 Installation Support
7.2.1 Base Operating Support Personnel
7.2.1.1 Military
7.2.1.2 Civilian
7.2.2 Real Property Maintenance Personnel
7.2.2.1 Military
7.2.2.2 Civilian
7.2.3 Installation Support Non-Pay

Algorithms and Factors

Different for each AF division and MDS

Cost Element	Algorithm
1.0 Unit Mission Personnel	
1.1 Operations	
1.1.1 Aircrew	F1 * F2 * (F4 + F5) * F66 + F1 * F2 * F6 * F67
1.2 Maintenance	
1.2.1 Organizational Maintenance	
1.2.1.1 Military Pay	F70 * F66 + F71 * F67
1.2.1.2 Civilian Pay	F72 * F31
1.2.2 Intermediate Maintenance	
1.2.2.1 Military Pay	F73 * F66 + F74 * F67
1.2.2.2 Civilian Pay	F75 * F31
1.2.3 Ordnance Maintenance	
1.2.3.1 Military Pay	F76 * F66 + F77 * F67
1.2.4 Other Maint Personnel	
1.2.4.1 Military Pay	F79XF66+F80XF67
1.2.4.2 Civilian Pay	F81 * F31
1.3 Other Mission Personnel	
1.3.1 Unit Staff	
1.3.1.1 Military Pay	F22 * F66 + F23 * F67
1.3.1.2 Civilian Pay	F24 * F31
1.3.2 Security	
1.3.2.1 Military Pay	F25 * F66 + F26 * F67
1.3.2.2 Civilian Pay	
1.3.3 Other	
1.3.3.1 Military Pay	F28 * F66 + F29 * F67
1.3.3.2 Civilian Pay	F30 * F31

Cost Factors

Factor Specifics

Information presented is representative, not actual data.

Input Code Number	Information Description	AFI 65-503 Table Factor, or Other Source	Date of Table Used	Date of Data	Factor from Table	Inflation Factor (if needed)	Normalized Factor
I	**Program Factors**						
F1	Total PAA	AFTOC	Avg FY96-04	2006	140.28		94.00
F2	Crew Ratio	Table A43-1	Mar-04		2.00		2.00
F3	FH/PAA/Yr	AFTOC	Avg FY96-04	2006	429.35		537.60
F3a	Number of Squadrons				8		19.00
F3b	Maintenance Personnel Spaces per PAA (SPA)	Derived from Table A43-1, 8 PAA	Mar-04		50.13		50.13
F4	Pilots/Crew	Table A37-1	Mar-04		2		2.0
		Drill Officer, derived from A43-1	Mar-04				1.2
		Civ Tech Officer, derived from A43-1	Mar-04				0.7
		AGR Officer, derived from A43-1	Mar-04				0.1
		Active Duty Officer, derived from A43-1	Mar-04				0.0
F5	Non-Pilot Officer/Crew	Table A37-1	Mar-04		1		1.0
		Drill Officer, derived from A43-1	Mar-04				0.6
		Civ Tech Officer, derived from A43-1	Mar-04				0.3
		AGR Officer, derived from A43-1	Mar-04				0.0
		Active Duty Officer, derived from A43-1	Mar-04				0.0
F6	Enlisted/Crew	Table A37-1	Mar-04		3		3.0
		Drill Enlisted, derived from A43-1	Mar-04				1.8
		Civ Tech Enlisted, derived from A43-1	Mar-04				1.0
		AGR Enlisted, derived from A43-1	Mar-04				0.2
		Active Duty Enlisteds, derived from A43-1	Mar-04				0.0
F7	Pilot Training Factor	Table A34-1	Jul-05	2005	$490,797.00	0.974	$503,898.36
F8	Non-Pilot Training Factor	Table A34-1	Jul-05	2005	$119,304.00	0.974	$122,488.71
F9	Enlisted Training Factor	Table A18-1A	Jun-03	2003	$31,639.00	0.914	$34,615.97

Specific MDS may utilize > 350 Cost Factors

Factor Specifics

Information presented is representative, not actual data.

Input Code Number	Information Description	AFI 65-503 Table Factor, or Other Source	Date of Table Used	Date of Data	Factor from Table	Inflation Factor (if needed)	Normalized Factor
F66	Officer Pay	Table A22-1, Civilian Technician Officer	Apr-04	2004	$66,575.00	0.936	$71,127.14
		Table A22-1, AGR Officer	Apr-04	2004	$133,961.00	0.936	$143,120.73
		Table A22-1, Drill Officer Rated	Apr-04	2004	$29,131.00	0.936	$31,122.86
		Table A22-1, Drill Officer Non-Rated	Apr-04	2004	$29,131.00	0.936	$31,122.86
		Table 19-2, Active Duty Officer	??	2006	$121,171.00	1	$121,171.00
F67	Enlisted Pay	Table A22-1, Civilian Technician Enlisted	Apr-04	2004	$66,575.00	0.936	$71,127.14
		Table A22-1, AGR Enlisted	Apr-04	2004	$75,625.00	0.936	$80,795.94
		Table A22-1, Drill Enlisted Crew	Apr-04	2004	$11,367.00	0.936	$12,144.23
		Table A22-1, Drill Enlisted Non-Crew	Apr-04	2004	$11,367.00	0.936	$12,144.23
		Table 19-2, Active Duty Enlisted	??	2006	$58,761.00	1	$58,761.00
F68	Non-Aircrew Officer Training	AFTOC OLAP, Avg of FY99-FY04		2006	$43.77	1	$43.77
F69	Non-Aircrew Enlisted Training	AFTOC OLAP, Avg of FY99-FY04		2006	$43.77	1	$43.77

Global Factors

Information presented is representative, not actual data.

Aircraft Counts

PAA				
	AD	AFRES	ANG	Total
C-130H	94	94	94	282
C-130J	49	27	16	92
	143	121	110	374
Crew Ratio				
C-130H	2.00	2.00	2.00	
C-130J	2.00	2.00	2.00	
FH/PAA				
	Active Duty	AFRES	ANG	
	22.4 hrs/crew/mo	15.5 hrs/crew/mo	11.5 hrs/crew/mo	
C-130H	537.6	537.6	537.6	
C-130J	537.6	372.0	276.0	
Maintainers	FY04 SPA rates			
	AD	AFRES	ANG	
C-130H	34.14	45.00	50.13	
C-130J	34.14	45.00	54.63	

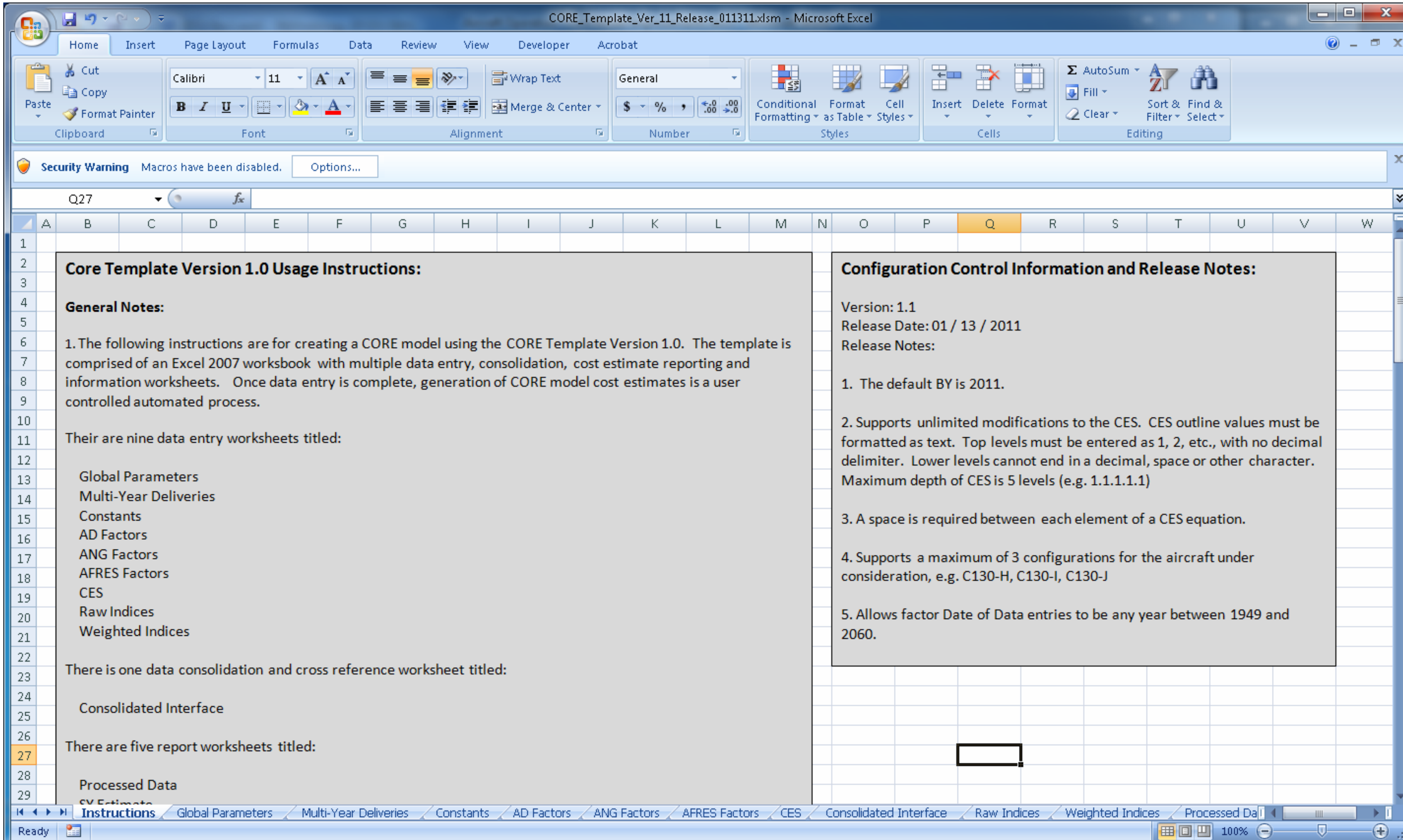
CORE Template

- All encompassing model that provides a consistent format for Aircraft O&S cost estimating across divisions, MDS, CY, FYDP and LCCEs.
- Act as an archive for WBS's, Algorithms and Factors.
- Minimize potential for data entry and cost calculation errors.

CORE Template Requirements

- Shall be an Excel based modeling tool and may include VB macros
- Shall accommodate base years 2000 to 2049
- Shall support estimates for all services: AD, ANG, AFR
- Shall produce both BY and TY estimates
- Shall include hyperlinks to factor tables in the AFTOC database
- Shall support analyst editing of WBS algorithms
- Shall include the OSD Excel Inflation Table Add-In
- Shall report costs for: CY, FYDP, LC by Service and MDS

CORE Template Format

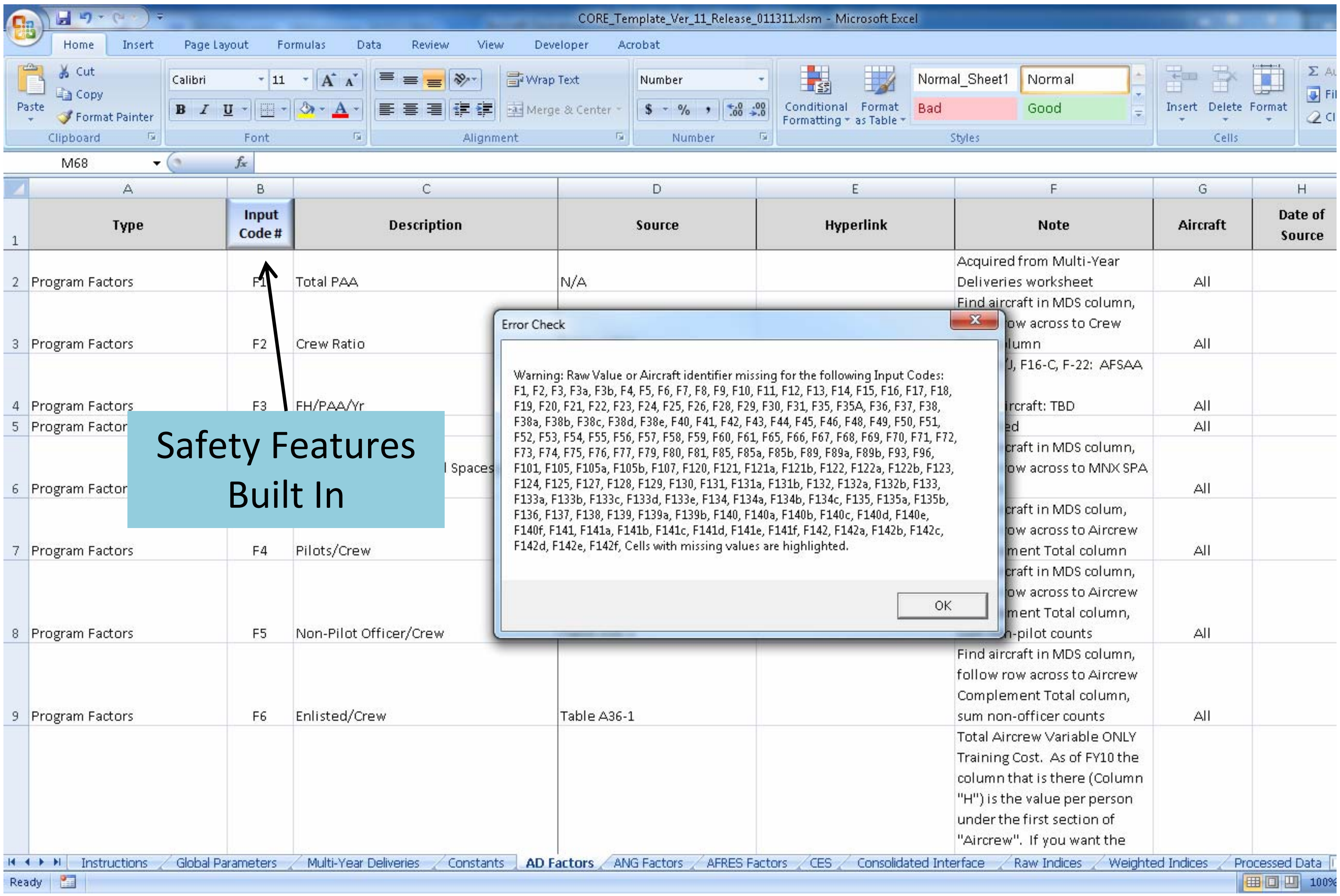


CORE Template Format

Outline	Title	Definition	Equation
1	Mission Personnel	The mission personnel element includes the cost of pay and allowances of officer, enlisted, and civilian personnel required to operate, maintain, and support a discrete operational system or deployable unit. This includes the personnel necessary to meet combat readiness, unit training, and administrative requirements. For units that operate more than one type of aircraft system, personnel requirements will be allocated on a relative workload basis. The personnel costs will be based on manning levels and skill categories. Note: Pay and allowances for officer and enlisted personnel should be based on the standard composite rate, which includes the following elements: basic pay, retired pay accrual, incentive pay, special pay, basic allowance for quarters, variable housing allowance, basic allowance for subsistence, hazardous duty pay, reenlistment bonuses, clothing allowances, overseas station allowances, uniform allowances, family separation allowances, separation payments, and social security contributions. Pay and allowances for civilian personnel should be based on the standard composite rate, which includes the following elements: basic pay, additional variable payments for overtime, holiday pay, night differentials, cost-of-living allowances, and the government contribution to employee benefits, insurance, retirement, and the Federal Insurance Contribution Act.	
1.1	Operations	The pay and allowances for the full complement of aircrew personnel required to operate a system.	
1.1.1	Pilot		(F1 * F2 * F4 * F66)
1.1.2	Aircrew	Aircrew composition includes the officers and enlisted personnel (pilot, non-pilot, and crew technicians) required to operate the aircraft of a deployable unit.	(F1 * F2 * F5 * F66) + (F1 * F2 * F6 * F67)

Editable Equations
Visual Basic Controlled Automatic Calculation

CORE Template Operation



Cost Per Flying Hour Risk Model

What Will Be Covered:

- What was the purpose and scope of the CPFH Risk Model
- What were CPFH cost elements and factors
- What was the considered approach for improving the CPFH Risk Modeling process
- What is the CPFH Risk Model Template

Purpose and Scope of the CPFH Risk Model

- Used to assess the probability of actual costs exceeding specific funding.
- Separate risk assessments performed for each operating agency and each platform type under its control.
- Challenge: Maintaining historical data, accumulating up-to-date information and incorporating historical inaccuracies.

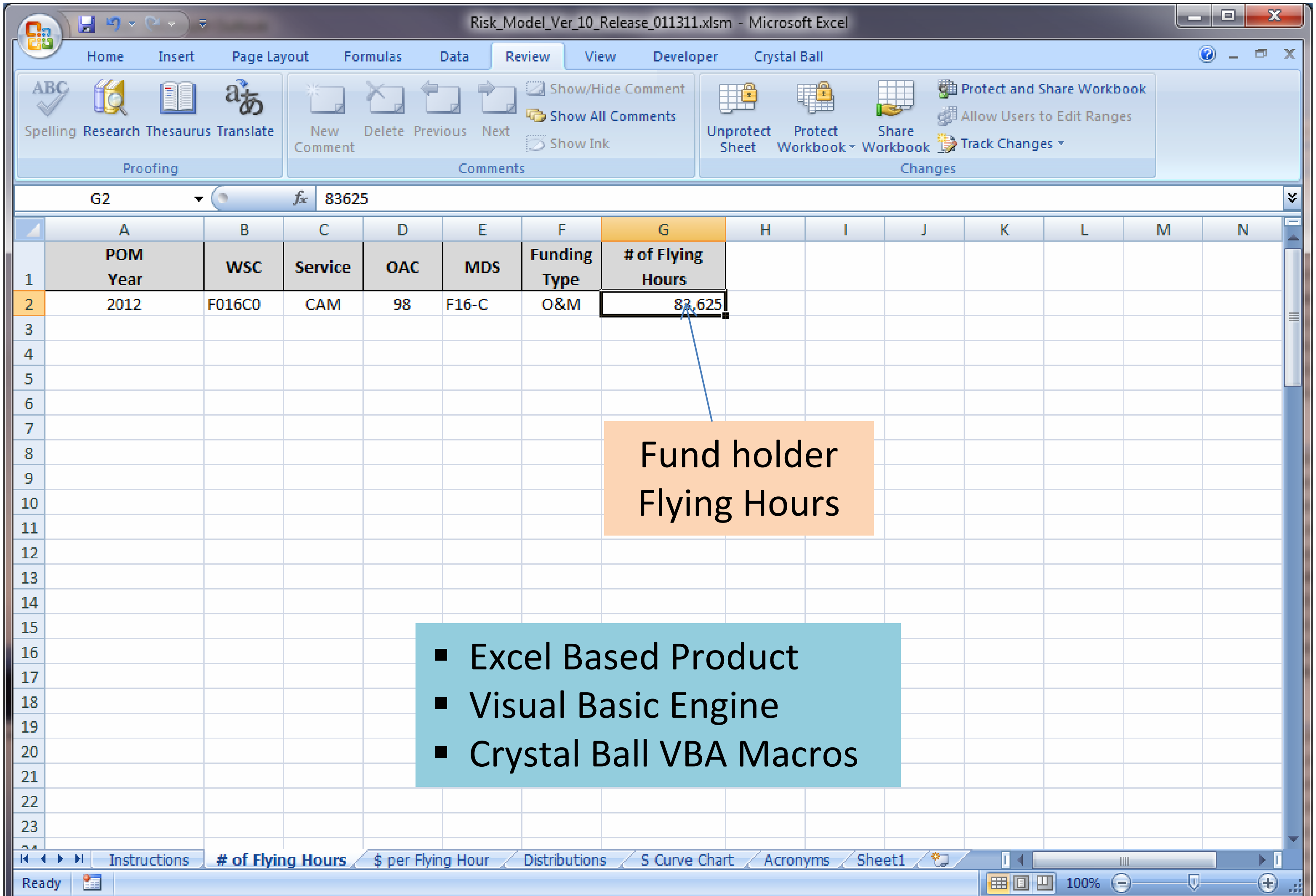
Approach for Improving the CPFH Risk Modeling Process

<u>Basic Premise:</u> Use historical inaccuracies to apply risk to future estimates.

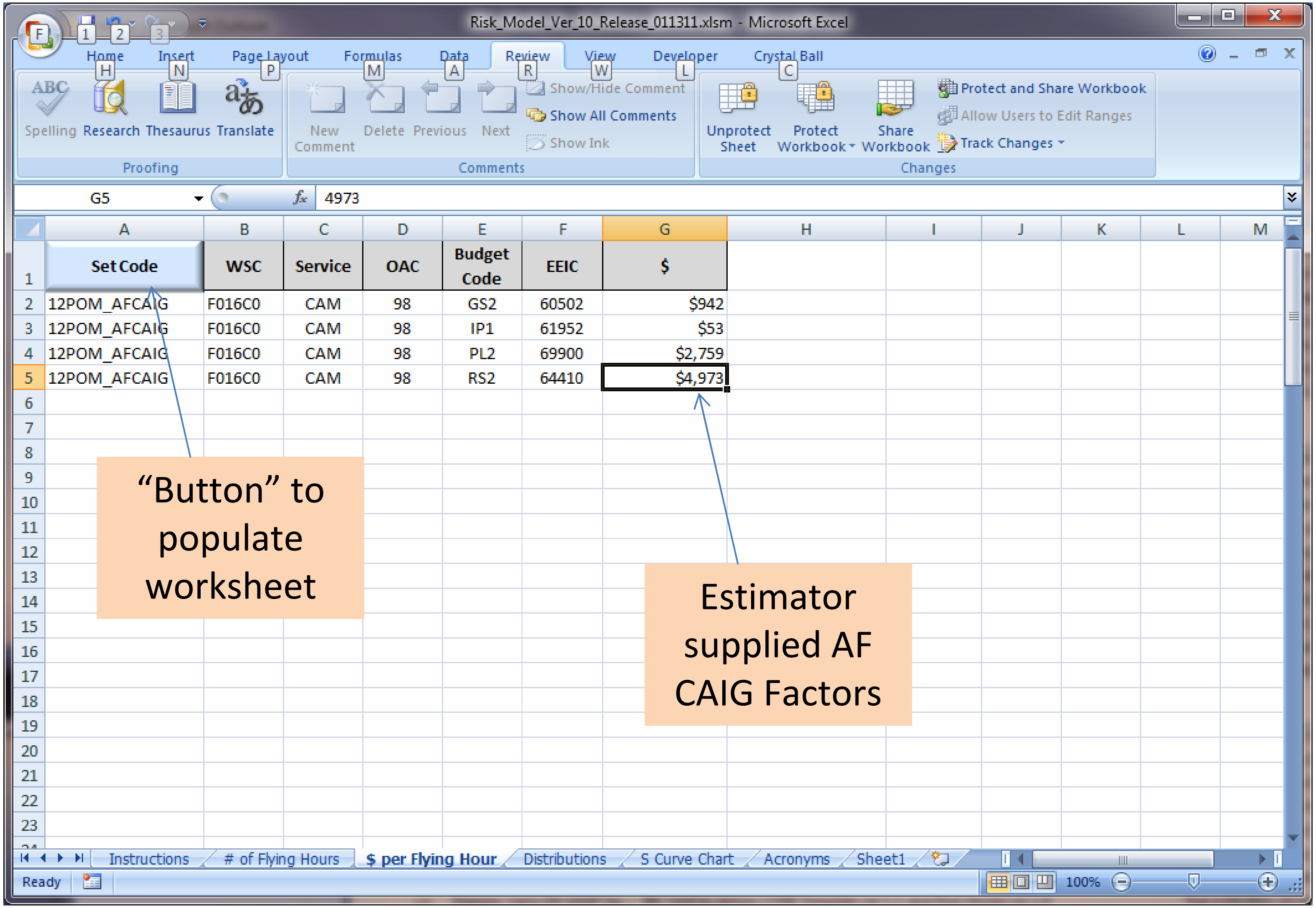
<u>Desired Result:</u> Over time, improved estimate accuracy.

<u>Model Responsibility:</u> Provide archive for historical cost data.

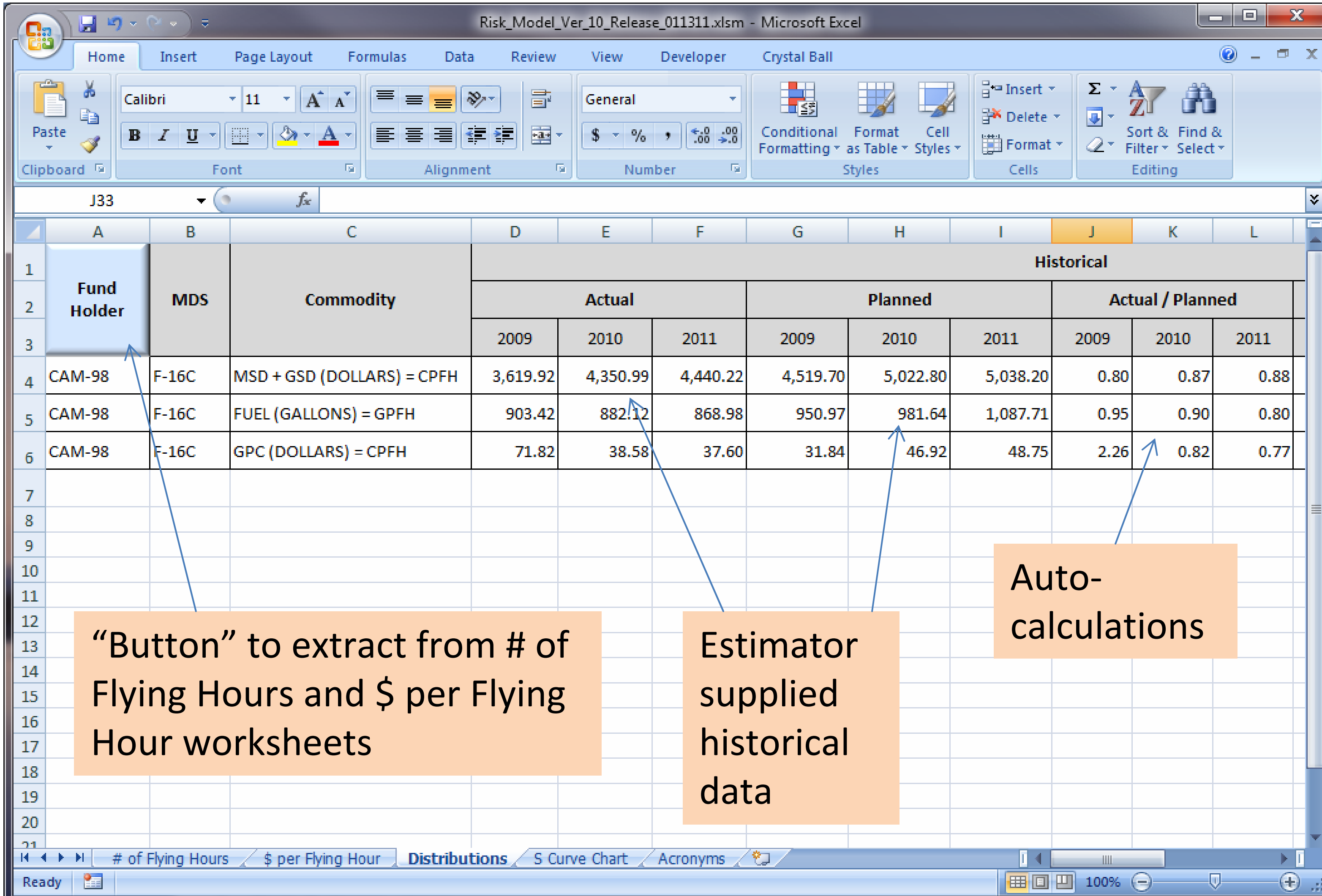
CPFH Risk Model Template



CPFH Risk Model Template

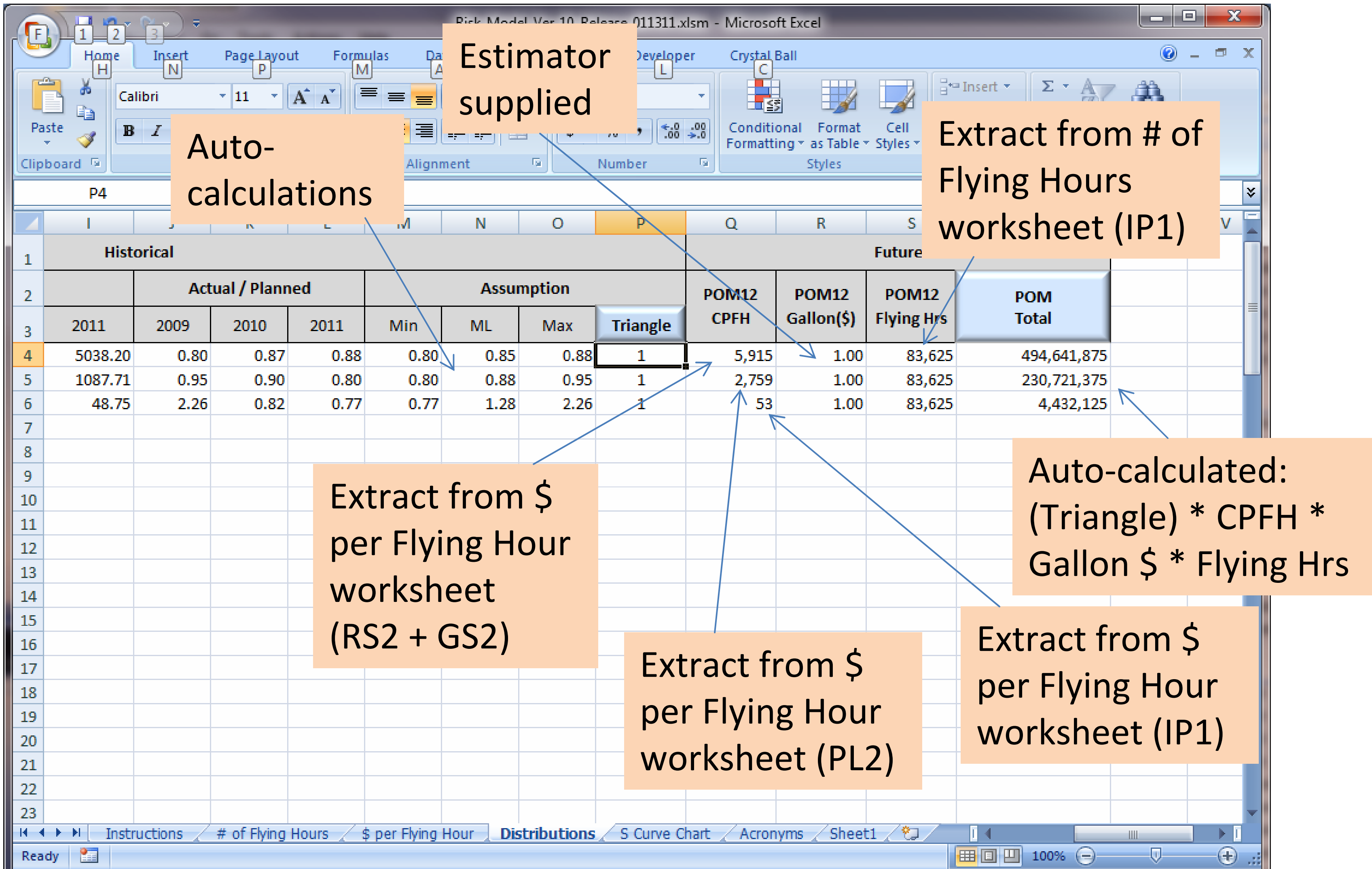


CPFH Risk Model Template



Fund Holder	MDS	Commodity	Historical Actual 2009	Actual 2010	Actual 2011	Planned 2009	Planned 2010	Planned 2011	Actual / Planned 2009	Actual / Planned 2010	Actual / Planned 2011
CAM-98	F-16C	MSD + GSD (DOLLARS) = CPFH	3,619.92	4,350.99	4,440.22	4,519.70	5,022.80	5,038.20	0.80	0.87	0.88
CAM-98	F-16C	FUEL (GALLONS) = GPFH	903.42	882.12	868.98	950.97	981.64	1,087.71	0.95	0.90	0.80
CAM-98	F-16C	GPC (DOLLARS) = CPFH	71.82	38.58	37.60	31.84	46.92	48.75	2.26	0.82	0.77

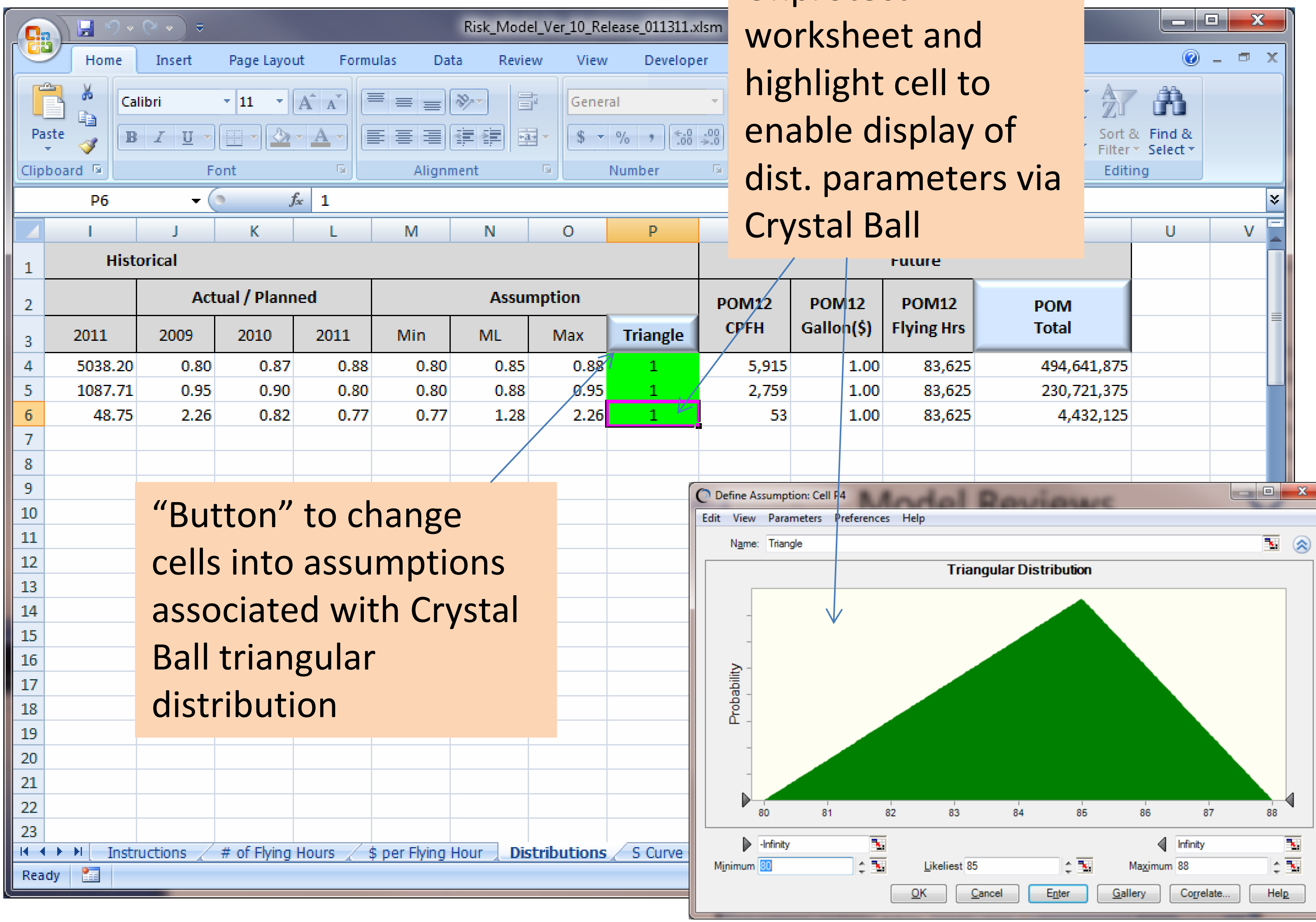
CPFH Risk Model Template



Historical								Future			
	Actual / Planned			Assumption				POM12 CPFH	POM12 Gallon($)	POM12 Flying Hrs	POM Total
2011	2009	2010	2011	Min	ML	Max	Triangle				
5038.20	0.80	0.87	0.88	0.80	0.85	0.88	1	5,915	1.00	83,625	494,641,875
1087.71	0.95	0.90	0.80	0.80	0.88	0.95	1	2,759	1.00	83,625	230,721,375
48.75	2.26	0.82	0.77	0.77	1.28	2.26	1	53	1.00	83,625	4,432,125

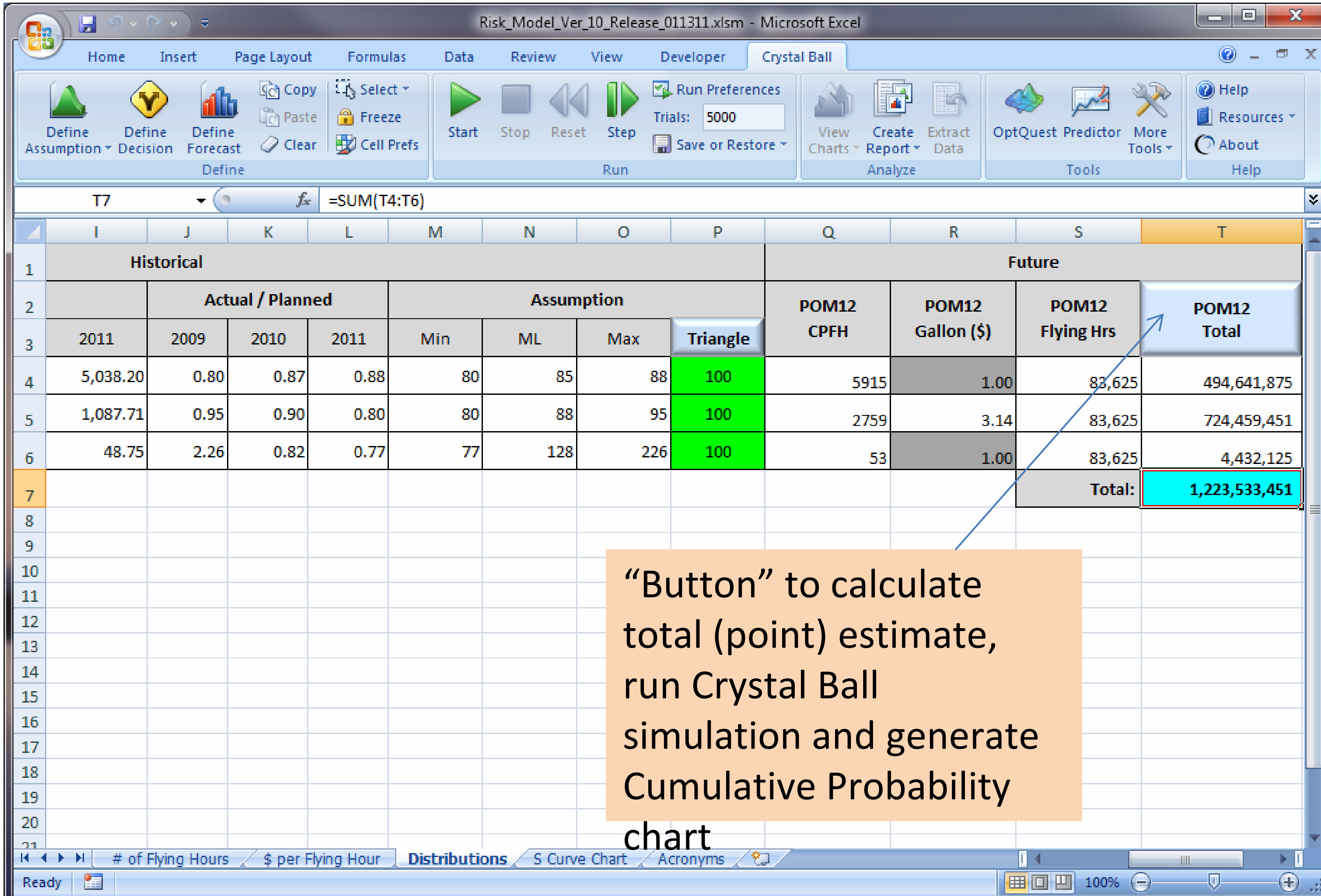
CPFH Risk Model Template

Unprotect worksheet and highlight cell to enable display of dist. parameters via Crystal Ball



"Button" to change cells into assumptions associated with Crystal Ball triangular distribution

CPFH Risk Model Template



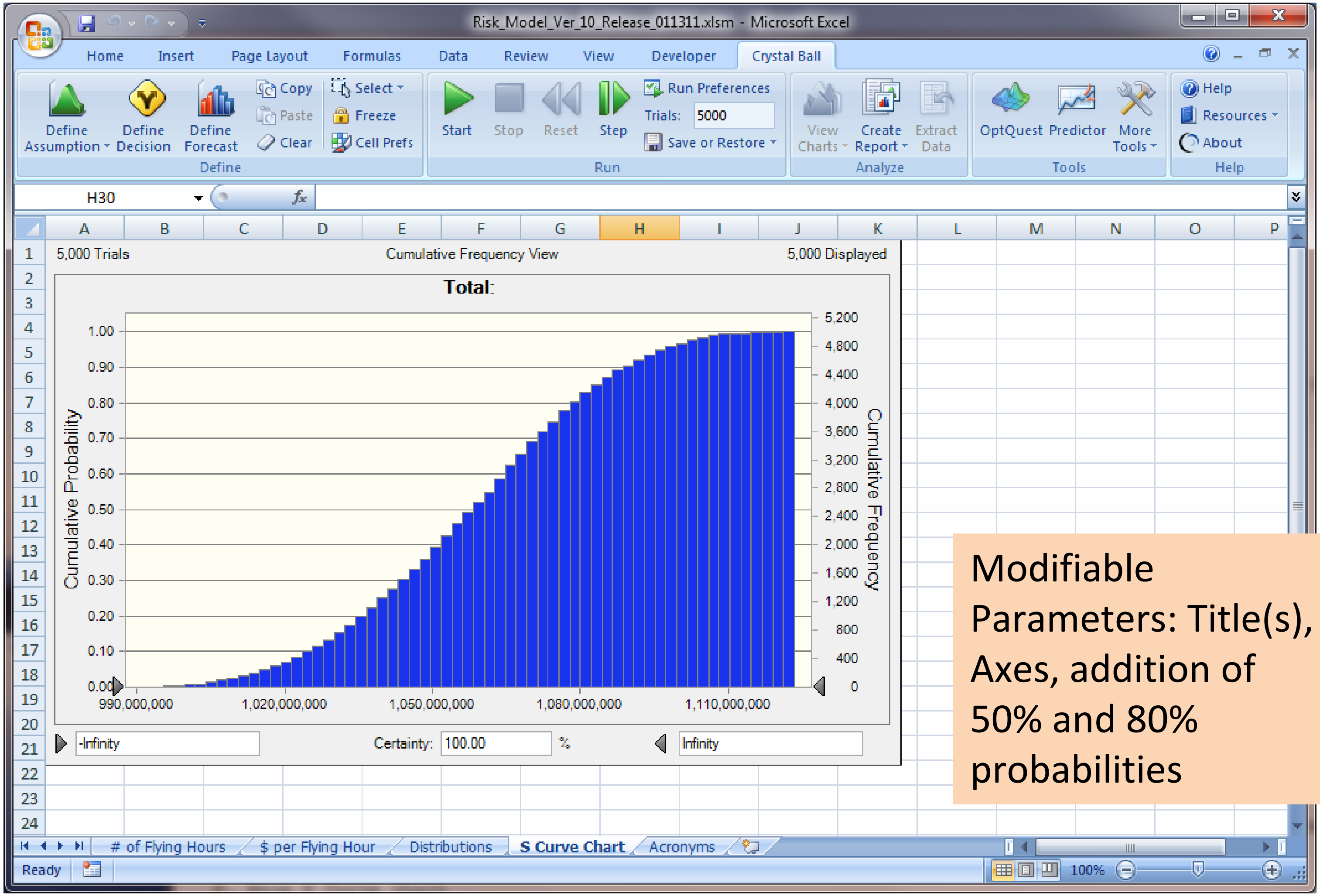
Risk_Model_Ver_10_Release_011311.xlsm - Microsoft Excel

T7 =SUM(T4:T6)

Historical								Future			
	Actual / Planned			Assumption				POM12 CPFH	POM12 Gallon ($)	POM12 Flying Hrs	POM12 Total
2011	2009	2010	2011	Min	ML	Max	Triangle				
5,038.20	0.80	0.87	0.88	80	85	88	100	5915	1.00	83,625	494,641,875
1,087.71	0.95	0.90	0.80	80	88	95	100	2759	3.14	83,625	724,459,451
48.75	2.26	0.82	0.77	77	128	226	100	53	1.00	83,625	4,432,125
										Total:	1,223,533,451

"Button" to calculate total (point) estimate, run Crystal Ball simulation and generate Cumulative Probability chart

CPFH Risk Model Template



Modifiable Parameters: Title(s), Axes, addition of 50% and 80% probabilities

Jet Engine Maintenance Cost Model

What Will Be Covered:

- What was to be the methodology and goal of the Jet
  Engine Maintenance Cost Model

Methodology and Goal, Jet Engine Cost Model

Methodology:

Simulate Jet Engine Flying Hours where engine module failures are random events.

Calculate averages for jet engine maintenance costs per year, per flying hour and time on the wing

Goal:

Derive the optimum value for a single Jet Engine maintenance decision variable: Overhaul Window Percentage.

This variable is the percent of a jet engine's maximum flying hours before overhaul after which a jet engine overhaul is performed in the event of a module failure.

Jet Engine Maintenance Cost Model Requirements

- Provide a tool to analyze optimal repair decisions that maximize engine time on the wing.
- Separately track up to 2000 engines and with up to 10 types of engine modules per engine.
- Produce time phased estimates over at least 75 years.
- Accommodate changing scheduled maintenance intervals and reliability profiles for engines and modules.

Equations of Interest

Average Cost Per Year:

Total Accumulated Cost / Simulation Years

Average Cost Per Flying Hour:

Total Accumulated Cost / (Simulation Years * Flying Hours Per Year)

Average Time On The Wing Per Year:

((Simulation Years * Flying Hours Per Year) - (Total Overhaul Time + Total Repair Time) / Simulation Years

Average Time On The Wing:

((Simulation Years * Hours Per Year) - (Total Accumulated Overhaul Time + Total Accumulated Repair Time) / Simulation Years

Module MTBF Probability Distribution

- The normal distribution is a continuous probability distribution that describes the probability of random events. Parameters for describing a normal distribution are mean and standard deviation.
- Some value of the unknown variable is the most likely value.
- The unknown variable could as likely be above or below the mean.
- The unknown variable is more likely to be close to the mean than far away, i.e. approx. 68% of the population samples will be within one standard deviation from the mean.

Acquisition Cost Probability Distribution

- The triangular distribution is commonly used when the minimum, maximum and most likely values are known.

- There are three conditions underlying the triangular distribution:
  - The minimum is fixed.
  - The maximum is fixed.
  - The most likely value falls at a point between the minimum and maximum values forming a triangular shaped distribution which shows that values near the minimum and maximum are less likely to occur than those near the most likely value.

Repair Cost Probability Distribution

- The beta distribution is for modeling empirical data and predict the random behavior of percentages and fractions.

- The parameters for describing the beta distribution are alpha and beta.

- There are two conditions underlying the beta distribution:
  - The unknown variable is a random value between a minimum and maximum.
  - The distribution shape is specified by positive values.

Model Architecture

- Simulates Flying Hours where module MTBF expressed in hours.
- When a module fails, a decision is made whether to overhaul the engine or repair the module, based on a single decision variable, “Overhaul Window Percent”.
- Overhaul Window Percent is the percent of the maximum flying hours before overhaul, after which an engine overhaul is performed in the event of a module(s) failure.
- This quantity can be varied to determine the optimum window size in terms of Average Cost Per Year and Average Time On The Wing Per Year.

Model Operation – User Interface

Two Data Entry Worksheets:

Global Parameters: Simulation Years

Aircraft and Engine Data: Engine and module performance data

Engine:

- First Maximum Hours Before Overhaul
- Mature Maximum Hours Before Overhaul Percent (ramp function)
- Overhaul Window Percent
- Overhaul Cost
- Overhaul Time

Model Operation – User Interface

Modules:

- Repair Cost
- Repair Time
- First mean Time Between Failure Hours
- First Failure Standard Deviation
- Mature Mean Time Between Failure Hours
- Mature Failure Standard Deviation

Simulation Results

- The customer specified engine and module factors and a range of Overhaul Window Percents.
- Simulations were run and optimum decision variable values were empirically derived, plotted, analyzed….
- Optimum values were different for minimum cost and maximum time on the wing results.
- Model enhancements will be necessary to unify results.

Summary

- Aircraft O&S Cost Estimating is a field of study subject to continuing research, automation and attempts to refine and enhance results.
- Minimally three separate estimating methodologies employed:
  - Resource Estimating
  - Cost Per Flying Hour vs. Commodity Cost Estimating
  - Maintenance Methodology Cost Estimating

Observation:

Advent of UAVs may significantly alter current approaches to manned aircraft O&S cost estimating.