U.S. Army Corps of Engineers – *A Risk-Informed Approach to Asset Management*

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US Army Corps of Engineers
BUILDING STRONG®

Study Recommendations

- **Recommendation 2** – Corporate approach to mitigating risk which focuses on linking investments to Mission and Objectives
- **Recommendation 3** - Use “risk” to inform annual maintenance and use standard methods for gathering and updating data
- **Recommendation 6** – Focus on collecting mission critical data and information

Study Recommendations

- **Recommendation 2 (Findings 1, 5 and 6)**.

Federal agencies should develop more strategic approaches for investing in facilities maintenance and repair to achieve beneficial outcomes and to mitigate risks. Such approaches should do the following:

- Identify and prioritize the outcomes to be achieved through maintenance and repair investments and link those outcomes to achievement of agencies' missions and other public policy objectives.
- Provide a systematic approach to performance measurement, analysis, and feedback.
- Provide for greater transparency and credibility in budget development, decision making, and budget execution.

Study Recommendations

- **Recommendation 3 (Findings 1, 2 and 3)**.

To develop more strategic approaches to maintenance and repair investment, federal agencies should do the following:

- Identify and prioritize the beneficial outcomes that are to be achieved through maintenance and repair investments, preferably in the form of a 5- to 10-year plan agreed on by all levels of the organization. Elements of this type of plan are outlined in Chapter 7.
- Establish a risk-based process for prioritizing annual maintenance and repair activities in the field and at the headquarters level. Guidance for doing this is contained in Chapter 7.
- Establish standard methods for gathering and updating data to provide credible, empirical information for decision support, to measure outcomes from investments in maintenance and repair, and to track and improve the results.

Study Recommendations

- **Recommendation 6 (Findings 6 and 8)**.

Federal agencies should avoid the collection of data that serve no immediate mission-related purpose. Agencies should employ a knowledge-based condition assessment approach. Outcome metrics and models should make maximum use of existing data. Where new or unique data are required to support the development of an outcome measure or model there should be a clearly defined benefit to offset the cost of collecting and maintaining those data

Civil Works "Value to the Nation"

~ $250B in Replacement Value

History of "Risk" in USACE O&M Budget

- 2007 for FY09 budget
  - ✓ Flood Risk Mgmt
- 2008 for FY10 budget
  - ✓ Hydropower
  - ✓ Navigation
    - Inland
    - Coastal
- 2010 for FY11 budget
  - ✓ Recreation
  - ✓ Environmental Stewardship

TABLE III-5

Relative Risk Value Matrix

Consequence Category (Condition / Consequence)	Condition Classification: F (Failed)	D (Inadequate)	C (Probably Inadequate)	B (Probably Adequate)	A (Adequate)
I	1	2	6	10	15
II	3	5	9	14	19
III	4	8	13	18	22
IV	7	12	17	21	24
V	11	16	20	23	25

Risk to Mission and Corps Responsibilities to the Public…our Value to the Nation!

Business Line Detailed Approaches

- Flood Risk Management
  - Dam and Levee Safety
  - FRM Operational Condition Assessment
- Hydropower
  - hydroAMP
  - Hydropower Modernization Initiative (HMI)
- Navigation
  - Inland
  - Coastal
- Recreation
  - "RecBEST" updated with Recreation Operational Condition Assessment

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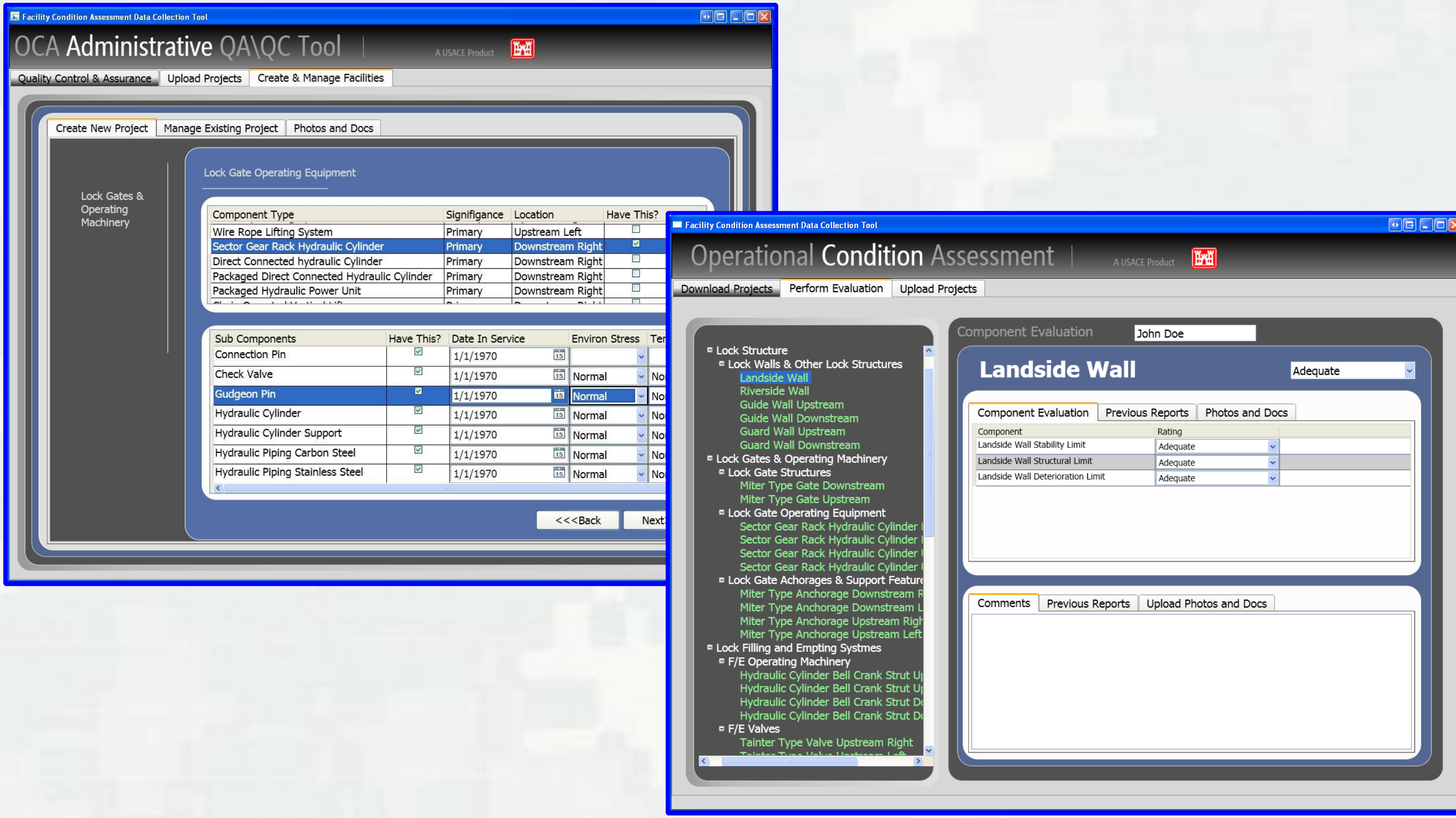
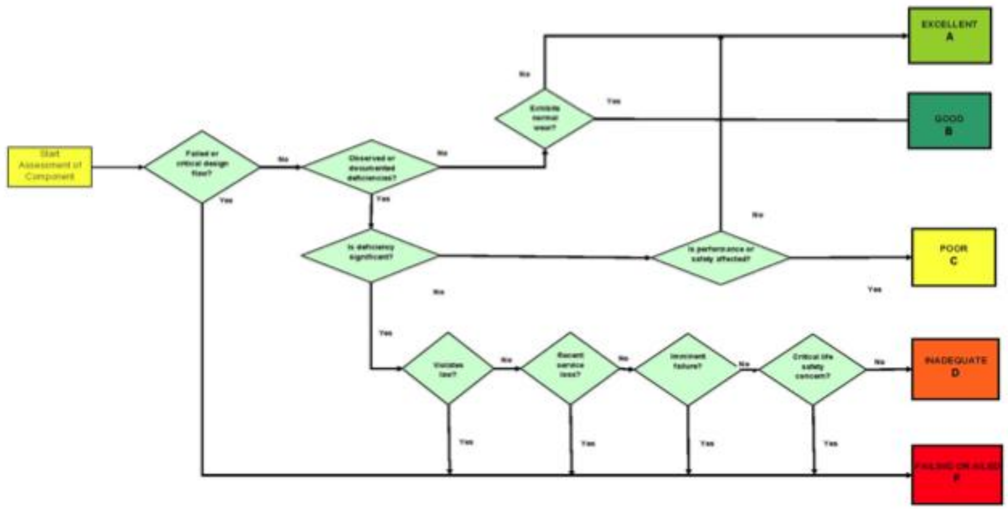
55% of navigation locks are > service life and in next decade it rises to 77%

OCA Tool – Build the Project



Standard (Component) Inventory across Corps Nav portfolio

Assigning Condition Ratings

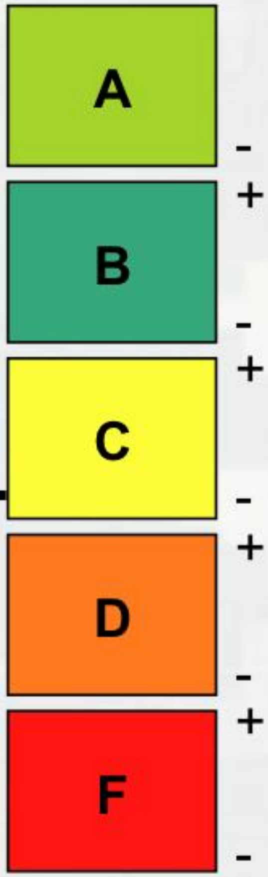


Condition Rating Logic/Flow Chart

Rating Increment	Rationale
Plus (+)	a. The components condition has worsened and the rating has dropped to the next lower rating since the last OCA inspection cycle. OR, b. There is no evidence, documented or observed, that the component's condition will continue to worsen to the next lower condition rating within the next OCA inspection cycle.
Neutral	a. The condition rating is the same as the last OCA inspection. OR, b) There is no definitive evidence, documented or observed, that the condition will worsen and drop to the next lower condition rating within the next OCA inspection cycle.
Minus (-)	a. There is definitive evidence, documented or observed, that the component's condition will worsen to the next lower condition rating level(s) within the next OCA inspection cycle. OR, b. If in a "failed" state, there is a high degree of confidence that the component will completely fail within the next OCA inspection cycle.

CONDITION RATING		DEFINITION
A	EXCELLENT	1) Has not failed AND 2) does not have critical design flaw AND 3) no documented or observed deficiencies based on available data or studies AND 4) does not show signs of normal wear
B	GOOD	1) Has not failed AND 2) does not have critical design flaw AND 3) no documented or observed significant deficiencies based on available data or studies AND 4) deficiencies do not impact performance or safety. Best condition rating allowed if component shows signs of normal wear.
C	POOR	1) Has not failed AND 2) does not have critical design flaw AND 3) no documented or observed significant deficiencies based on available data, studies, or observed project performance issue AND 4) deficiencies do impact performance or safety.
D	INADEQUATE	1) Has not failed AND 2) does not have critical design flaw AND 3) has documented or observed significant deficiencies based on available data, studies, or has an observed project performance issue AND 4) does not violate law, failure is not imminent before next OCA, has not experienced closure/loss of service due to current condition in recent history, and no critical life safety concern exists.
F	FAILING OR FAILED	1) Has failed OR 2) has critical design flaw OR 3) has documented or observed significant deficiencies based on available data, studies, or has an observed project performance issue AND one or more of the following is true; violates law, failure is imminent before next OCA, has experienced closure/loss of service due to current condition in recent history, or critical life safety concern exists.

Consistent and Repeatable Process!



OCA Baseline Risk Process

Establishes all risk metrics in relationship to two primary criteria:

- Mission -- the combination of adverse conditions and consequences that would occur from a **component failure**, *resulting in an inability to lock traffic and/or maintain the navigation pool* and
- Safety -- the combination of adverse conditions and consequences that would occur from a **component failure**, *resulting in exposure of the project personnel and end users to life safety impacts*

Probability of Operational Failure X *Consequence of Failure*
(Unsatisfactory Performance)

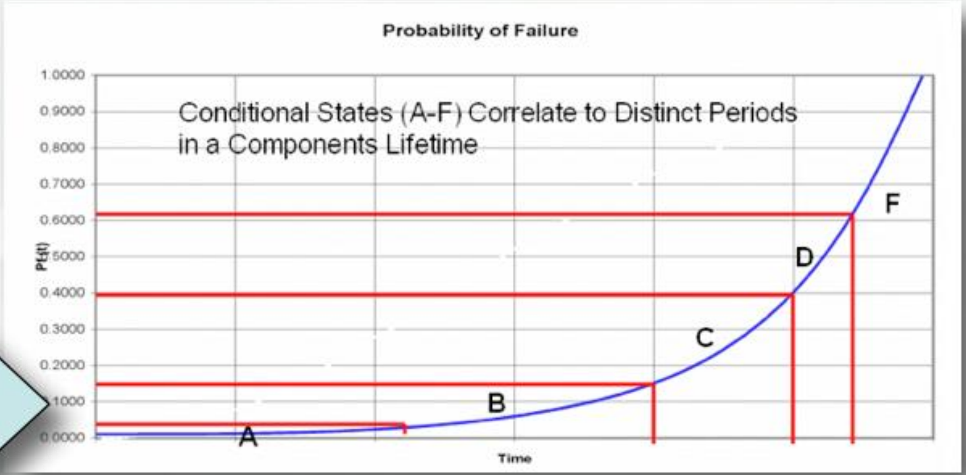
Probability of Operational Failure X *Consequence of Failure*

(Unsatisfactory Performance)

1. Correlate OCA ratings with component lifetime trend, F(t)

2. Consider component importance

3. Derive probability of failure from formal engineering methods (future)



Condition Rating	Numeric Condition Value	Surrogate Probability of Failure/Reliability	
		P(f)	R
Complete Failure	10	1	0
F-	9.325	.9325	.0675
F	7.995	.7795	.2005
F+	6.665	.6665	.3335
D-	5.675	.5675	.4325
D	5.005	.5005	.4995
D+	4.335	.4335	.5665
C-	3.575	.3575	.6425
C	2.745	.2745	.7255
C+	1.915	.1915	.8085
B-	1.325	.1325	.8675
B	0.995	.0995	.9005
B+	0.665	.0665	.9335
A-	0.417	.0417	.9583
A	0	0	1

Probability of Operational Failure X *Consequence of Failure*
(Unsatisfactory Performance)

1. Correlate OCA ratings with component lifetime trend, F(t)
2. Consider component importance
3. Derive probability of failure from formal engineering methods (future)

The OCA tool calculations take into consideration the following variables:

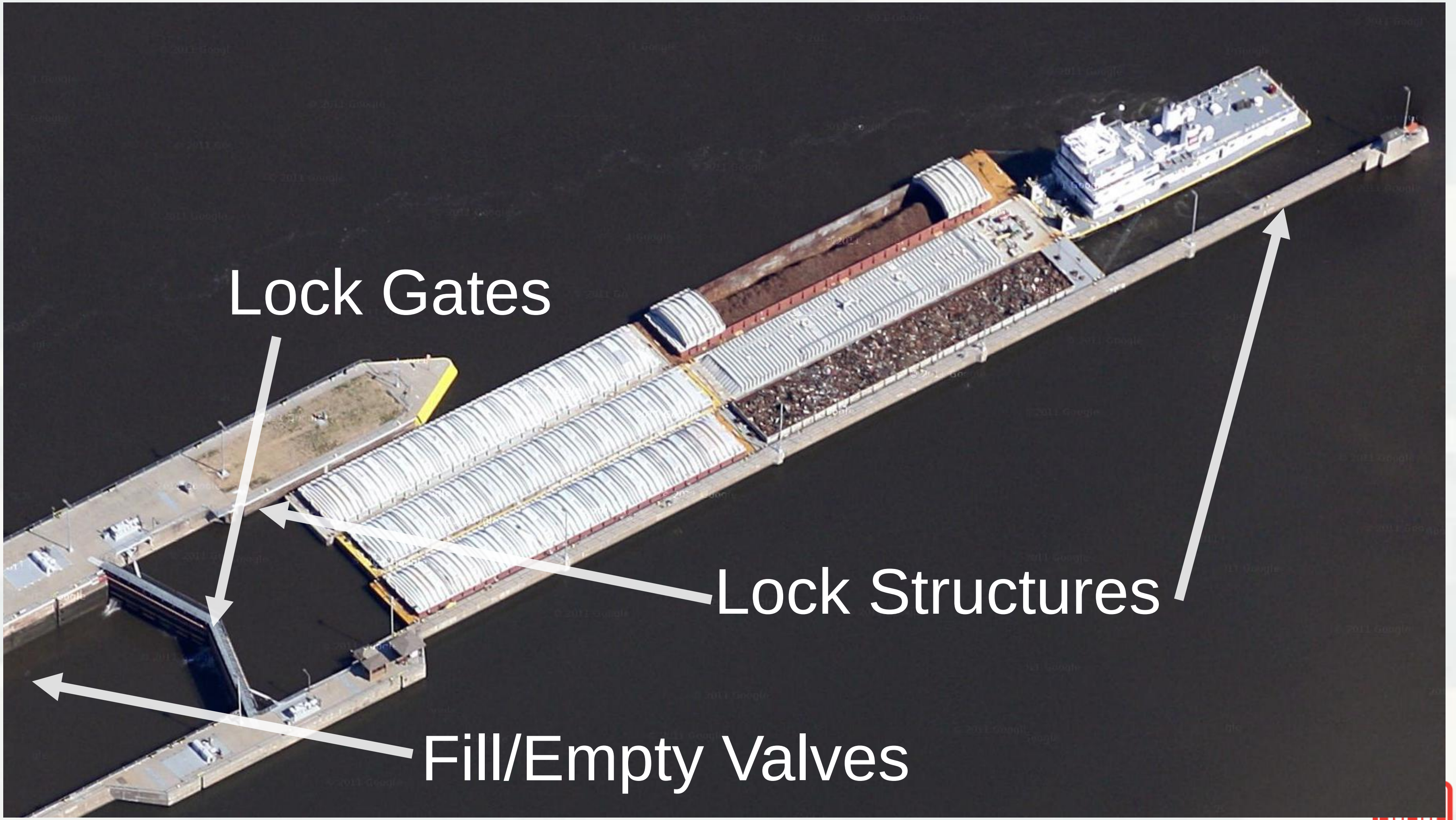
- Component Condition established through the OCA process
- Component Importance to Mission
- Component Importance to Safety
- Component Redundancy
- Mission Related Consequences (Monetary and Non-Monetary) that result from Component Failure.
- Safety Related Consequences that result from Component Failure

Mission Critical Components

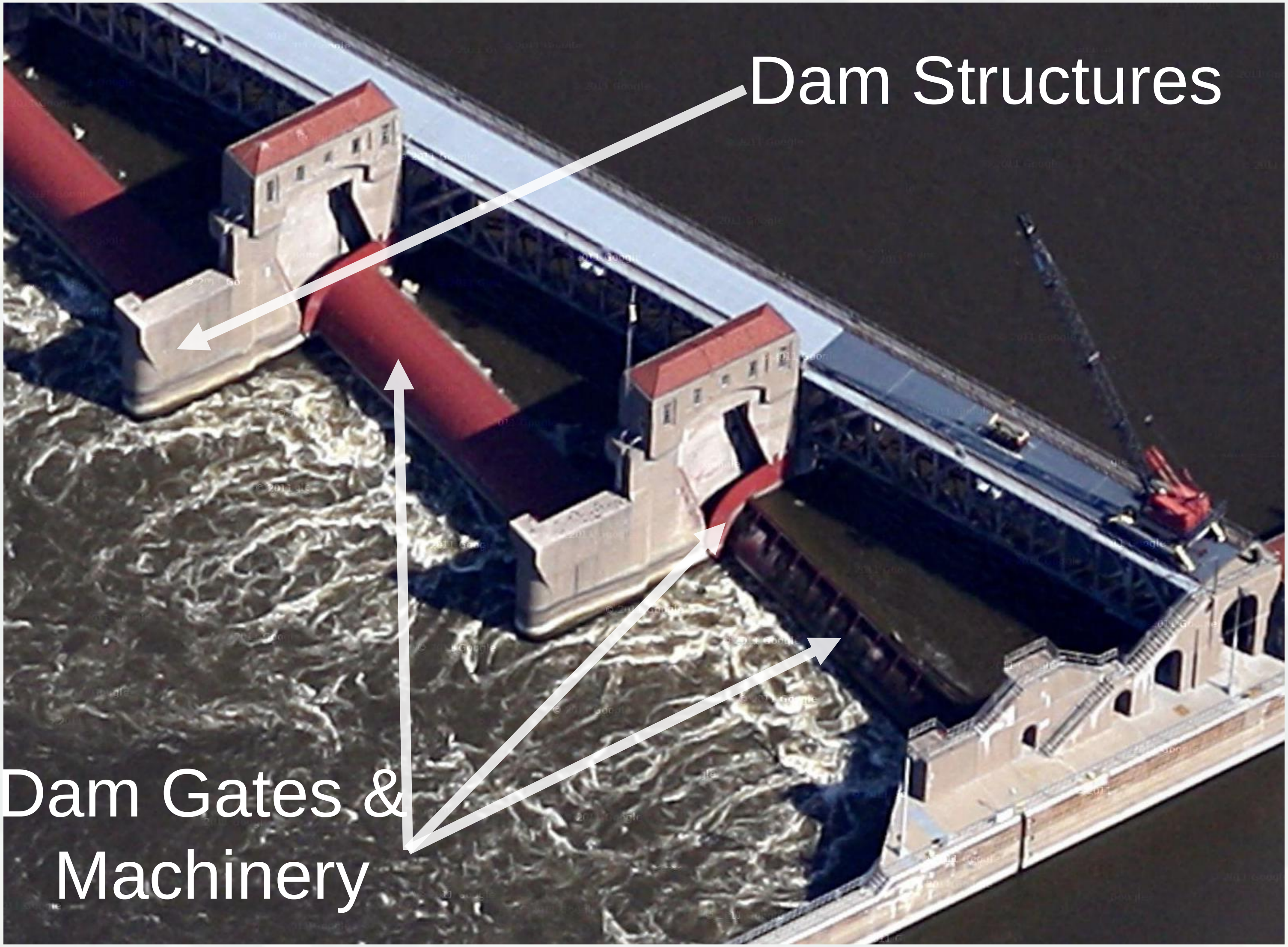
For Inland Navigation a component is Mission Critical IF its failure results in the:

1. Inability to lock (pass) traffic and/or
2. Inability to maintain the navigation pool

Examples – Pass Traffic



Examples – Maintain Pool



Examples – NON-Critical

Component	Component Importance/Redundancy/Impact								
	Component Importance Factors		Component Mission Crticiality (Yes or No)	Component Support By Existing Redundant System(s) (Yes or No)	Typical Available Degree of Redundancy (2 = more than 2 indential systems , 1 = at least one idential system, None =0)		Impact Recovery Duration		
	Mission	Safety			Low	High	Low	Average	High
Land Wall	96.24	75.98	Y	N	0	0	5	60	120
Middle Wall	96.24	75.98	Y	N	0	0	5	60	120
River Wall	96.24	75.98	Y	N	0	0	5	60	120
Gate Sill	91.18	60.78	Y	N	0	0	5	30	60
Guard Sill	91.18	60.78	Y	N	0	0	5	30	60
Piers	87.25	64.29	Y	N	0	0	0	60	120
Abutment	87.25	11.94	Y	N	0	0	0	30	60
Fixed Crest Dam	87.25	64.29	Y	N	0	0	0	90	180
Fixed Crest Weir	87.25	64.29	Y	N	0	0	0	90	180
Gate Sill (Overflow)	87.25	64.29	Y	N	0	0	0	60	120
Wicket Sills	87.25	64.29	Y	N	0	0	0	60	120
Gate Anchorage (Embedded)	86.91	50.85	Y	N	0	0	5	15	30
Pintle	86.91	39.76	Y	N	0	0	5	10	20
Lift Gate	86.91	73.97	Y	N	0	0	0	30	60
Miter Gate	86.91	73.97	Y	N	0	0	0	30	60
Roller Gate	86.91	73.97	Y	N	0	0	0	30	60
Sector Gate	86.91	73.97	Y	N	0	0	0	30	60
Filling/Emptying Culverts & Ports	86.11	50.65	Y	Y/N	0	1	0	15	30
Operating Machinery, Lifting Chains	83.22	73.97	Y	N	0	0	5	10	15
Utility Crossovers/Tunnels	83.07	50.65	Y	N	0	0	0	0	0
Guard Wall	80.03	75.98	Y	N	0	0	0	30	60
Guide Wall	80.03	75.98	Y	N	0	0	0	30	60
Operating Machinery, Electric	78.59	73.97	Y	N	0	0	1	5	15
Operating Machinery, Hydraulic	78.59	73.97	Y	N	0	0	1	5	15
Nose Pier	78.01	50.65	Y	N	0	0	0	30	60
Pier	78.01	75.98	Y	N	0	0	0	30	60
Anchorage Bars & Pins (Exposed)	76.74	50.85	Y	N	0	0	1	15	30
Contact Blocks	76.74	27.74	Y	N	0	0	1	5	10
Quoin Blocks	76.74	27.74	Y	N	0	0	1	15	30
Scour Protection	73.48	9.18	Y	N	0	0		0	
Fenders	72.94	60.78	Y	Y	2	2	1	2	3
Commercial Power Service Line	72.25	62.15	Y	Y/N	0	1	1	3	5
Main Disconnect Switch	72.25	62.15	Y	N	0	0	1	3	5
Motor Control Center	72.25	62.15	Y	N	0	0	1	3	5
Power Distribution Subpanel	72.25	62.15	Y	N	0	0	1	3	5
Primary Feeder	72.25	62.15	Y	Y/N	0	1	1	5	5
Primary Power Distribution Panel	72.25	62.15	Y	N	0	0	1	3	5
Switchboard	72.25	62.15	Y	N	0	0	1	5	10
Switchgear	72.25	62.15	Y	N	0	0	1	5	10
Transformer	72.25	62.15	Y	N	0	0	1	3	5
Operating Machinery, Electric Drive	70.22	16.52	Y	N	0	0	1	5	15
Operating Machin [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	15
Valve Frames (Er [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	15
Butterfly Valve	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	15
Stonybrook Valve	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	15

Just because a component is 'critical' doesn't mean it is equally important everywhere!!

Probability of Operational Failure X *Consequence of Failure*

(Unsatisfactory Performance)

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								30	60
								30	60
								30	60
								30	60
								15	30
								10	15
								0	0
								30	60
								30	60
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								30	60
								15	30
								5	10
								15	30
								0	
								2	3
								3	5
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								5	10
								5	10
								3	5
								5	15
								5	15
								10	15
								10	15
								10	15

Monetary Impacts Based on Impact Recovery Duration (loss of mission)

Recovery Durations:

- Developed thru collaborative efforts of SME's with experience in reaction to sudden failures and subsequent closures of lock and dams
- Not all components in OCA will result in loss of mission, this effect serves to define mission and non-mission critical components

Economic Losses to Commercial Shippers

- Daily economic shipper costs computed by USACE Planner Center of Expertise for Navigation

Probability of Operational Failure X Consequence of Failure

(Unsatisfactory Performance)

Project	Costs in thousands of dollars										
	1	3	5	10	15	30	45	60	90	180	365
Mississippi L&D 20	$ 60	$ 793	$ 1,880	$ 5,690	$ 11,123	$ 31,492	$ 54,653	$ 76,796	$ 122,225	$ 252,978	$ 519,871
Mississippi L&D 21	$ 105	$ 1,061	$ 1,966	$ 6,318	$ 12,016	$ 35,176	$ 60,602	$ 86,001	$ 137,732	$ 287,052	$ 563,878
Mississippi L&D 22	$ 78	$ 799	$ 2,288	$ 6,613	$ 13,096	$ 36,648	$ 63,072	$ 88,715	$ 140,593	$ 297,791	$ 569,813
Mississippi L&D 24	$ 86	$ 933	$ 2,359	$ 7,890	$ 13,746	$ 39,652	$ 68,674	$ 96,828	$ 152,457	$ 316,769	$ 594,758
Mississippi L&D 25	$ 60	$ 876	$ 2,015	$ 6,060	$ 11,776	$ 34,462	$ 59,596	$ 84,974	$ 134,126	$ 290,091	$ 599,572
Mississippi L&D 27	$ 49	$ 323	$ 1,025	$ 5,336	$ 8,806	$ 22,203	$ 42,448	$ 65,644	$ 101,272	$ 212,426	$ 442,081
Mississippi L&D 3	$ 34	$ 276	$ 695	$ 2,280	$ 4,441	$ 13,119	$ 22,126	$ 30,960	$ 48,167	$ 98,366	$ 146,818
Mississippi L&D 4	$ 33	$ 431	$ 864	$ 3,012	$ 5,598	$ 15,132	$ 25,143	$ 34,706	$ 53,935	$ 113,635	$ 161,392
Mississippi L&D 5	$ 47	$ 424	$ 1,164	$ 2,926	$ 5,557	$ 14,773	$ 24,471	$ 34,207	$ 55,330	$ 116,972	$ 167,803
Mississippi L&D 5A	$ 29	$ 443	$ 1,107	$ 2,591	$ 5,031	$ 14,244	$ 24,616	$ 34,968	$ 55,692	$ 118,151	$ 169,133
Mississippi L&D 6	$ 53	$ 409	$ 1,072	$ 3,504	$ 6,752	$ 17,882	$ 30,175	$ 42,579	$ 68,089	$ 145,038	$ 208,903
Mississippi L&D 7	$ 37	$ 484	$ 1,197	$ 3,479	$ 6,150	$ 17,651	$ 30,297	$ 42,878	$ 68,975	$ 144,545	$ 208,819
Mississippi L&D 8	$ 53	$ 488	$ 1,252	$ 3,290	$ 6,385	$ 18,565	$ 32,385	$ 45,561	$ 72,158	$ 152,236	$ 222,203
Mississippi L&D 9	$ 67	$ 599	$ 1,244	$ 4,007	$ 7,569	$ 21,062	$ 35,699	$ 48,868	$ 77,340	$ 165,761	$ 243,636
Mogantown L&D	$ 2	$ 26	$ 84	$ 94	$ 184	$ 458	$ 796	$ 1,127	$ 1,721	$ 3,525	$ 7,448
Monongahela L&D 3	$ 1	$ 5	$ 8	$ 370	$ 378	$ 400	$ 424	$ 448	$ 493	$ 632	$ 918
Monongahela L&D 4	$ 32	$ 326	$ 631	$ 1,586	$ 2,923	$ 7,757	$ 13,087	$ 18,790	$ 30,072	$ 63,496	$ 132,513
Montgomery L&D	$ 61	$ 622	$ 857	$ 2,655	$ 4,303	$ 10,428	$ 18,619	$ 28,421	$ 44,275	$ 91,990	$ 189,928
Montgomery Point L&D	$ 33	$ 293	$ 733	$ 2,006	$ 3,511	$ 10,314	$ 17,922	$ 25,567	$ 39,766	$ 83,917	$ 173,793
Moore Haven L&D	$ 0	$ 1	$ 3	$ 5	$ 9	$ 15	$ 23	$ 31	$ 46	$ 92	$ 187
Murray L&D	$ 14	$ 206	$ 515	$ 1,321	$ 2,415	$ 7,533	$ 11,919	$ 18,159	$ 27,873	$ 58,603	$ 123,820
New Cumberland L&D	$ 11	$ 82	$ 140	$ 1,444	$ 1,758	$ 2,622	$ 3,418	$ 4,375	$ 6,150	$ 10,637	$ 21,078
New Savannah Bluff L&D	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Newburgh L&D	$ 80	$ 651	$ 1,308	$ 5,020	$ 8,991	$ 22,957	$ 41,494	$ 64,540	$ 103,793	$ 217,052	$ 451,102
Newt Graham L&D	$ 7	$ 130	$ 277	$ 844	$ 1,710	$ 4,670	$ 8,108	$ 11,201	$ 17,857	$ 39,232	$ 81,153
Nickajack L&D	$ 21	$ 78	$ 208	$ 518	$ 967	$ 2,569	$ 4,408	$ 6,105	$ 9,835	$ 20,539	$ 42,358
Norrell L&D	$ 26	$ 365	$ 756	$ 2,071	$ 3,422	$ 9,963	$ 16,567	$ 23,356	$ 37,414	$ 81,461	$ 170,264
Ohio River L&D 52	$ 56	$ 534	$ 1,166	$ 3,855	$ 7,099	$ 18,703	$ 33,242	$ 49,448	$ 77,874	$ 162,147	$ 336,019
Ohio River L&D 53										$ 28,743	$
Old Hickory L&D										$ 32,057	$
Old River L&D										$ 75,067	$

Economic Losses to Commercial Shippers

Probability of Operational Failure X Consequence of Failure

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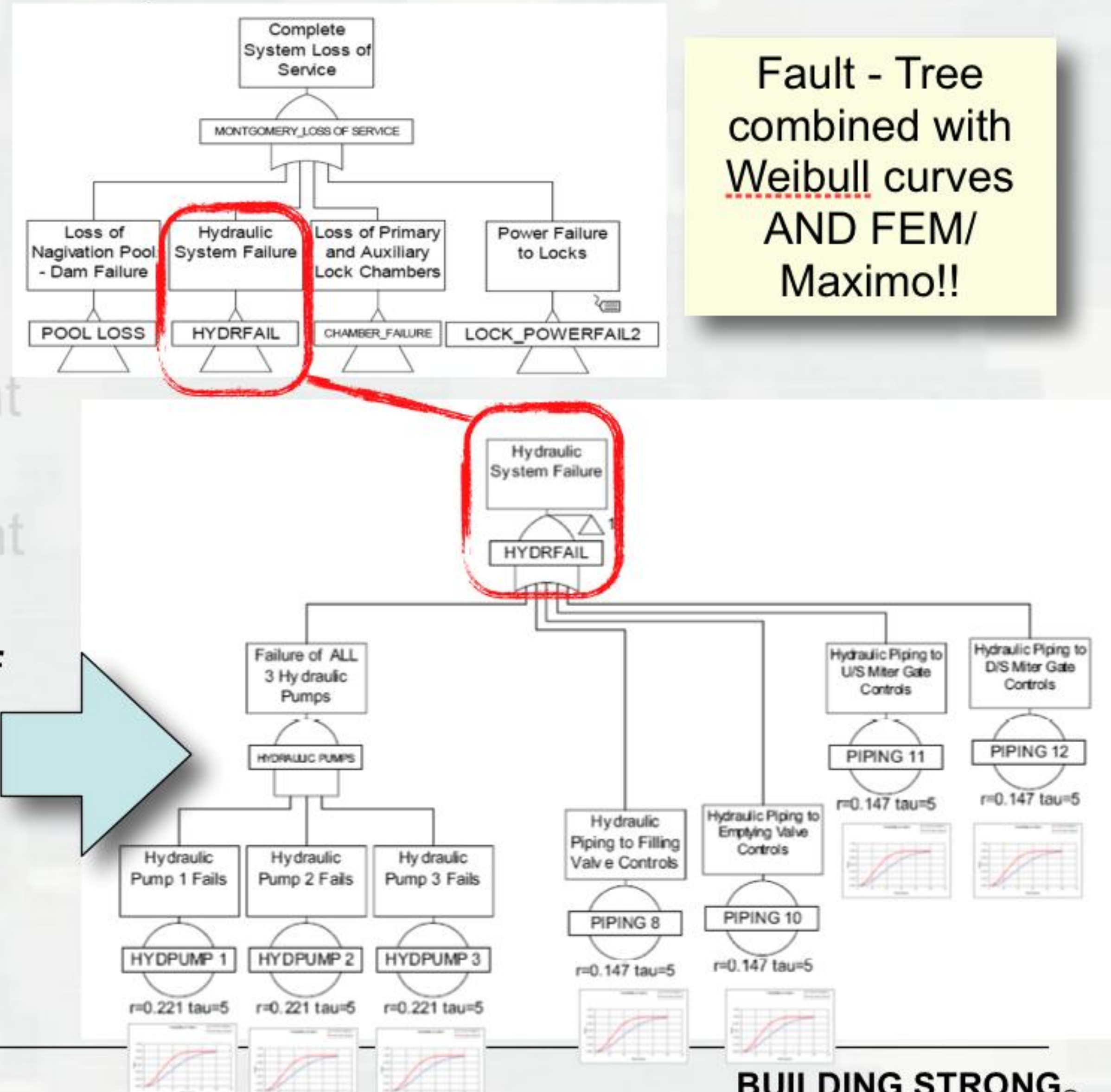
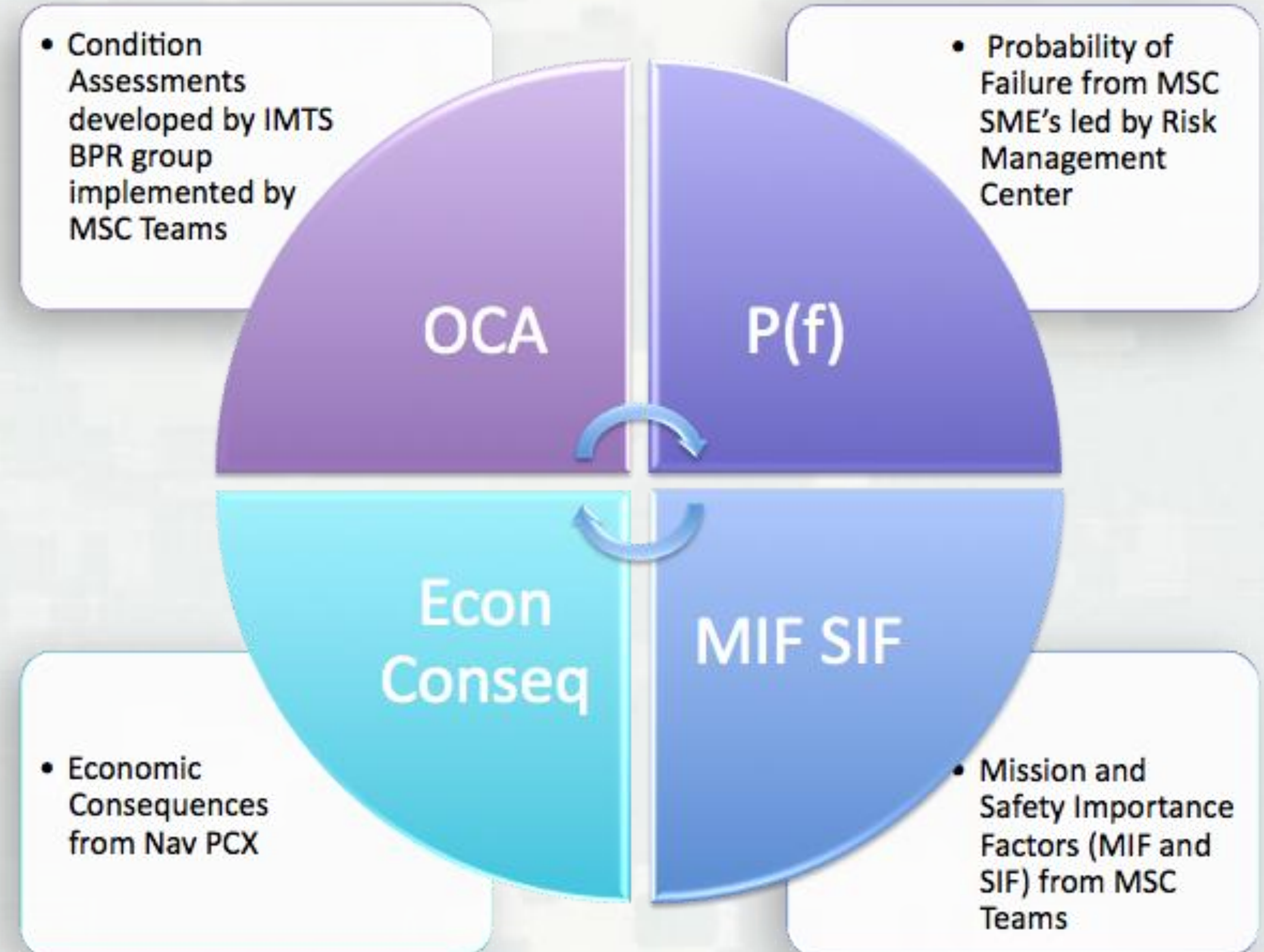
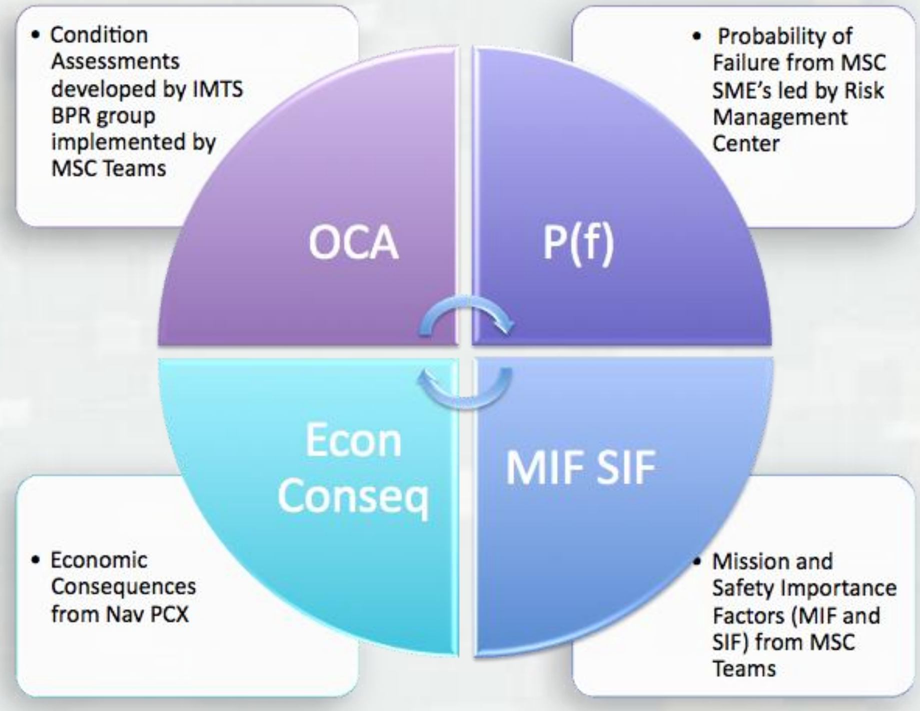


Fault - Tree combined with Weibull curves AND FEM/ Maximo!!



Condition by itself does NOT tell the complete and compelling story!!

Informing Critical Routine (Annual) Maintenance

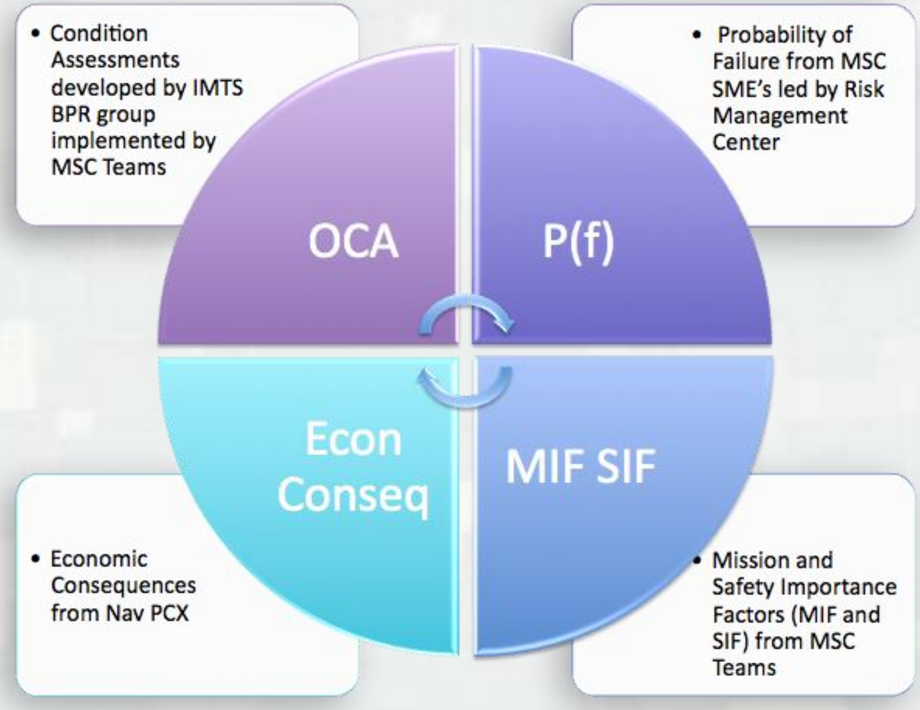


Maintenance accomplished sustains or improves condition and P(f) of these critical components

Importance Factors *inform* WHAT is most important to focus on in the corporate maintenance strategy

Consider Consequences and can now inform Assessment and Inspection Frequencies!

Data – A Key Enabler



- Source Data – eg Waterborne Commerce data from the Navigation Data Center
- OCA/ORA Data Enables:
  - ✓ Analysis by System, Sub-System and/or Component
  - ✓ Analytics to determine:
    - "Total Risk Exposure"
    - "Potential Risk Buy Down"
    - Inform Capital Investment Strategies

Don't forget QA/QC of the data!!

Study Recommendations

- ✓**Recommendation 2** – Corporate approach to mitigating risk which focuses on linking investments to Mission and Objectives
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Thank You!

Questions?