

Degraded Modes of Operations in Software Engineering

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Aging, Complex Critical Infrastructures...



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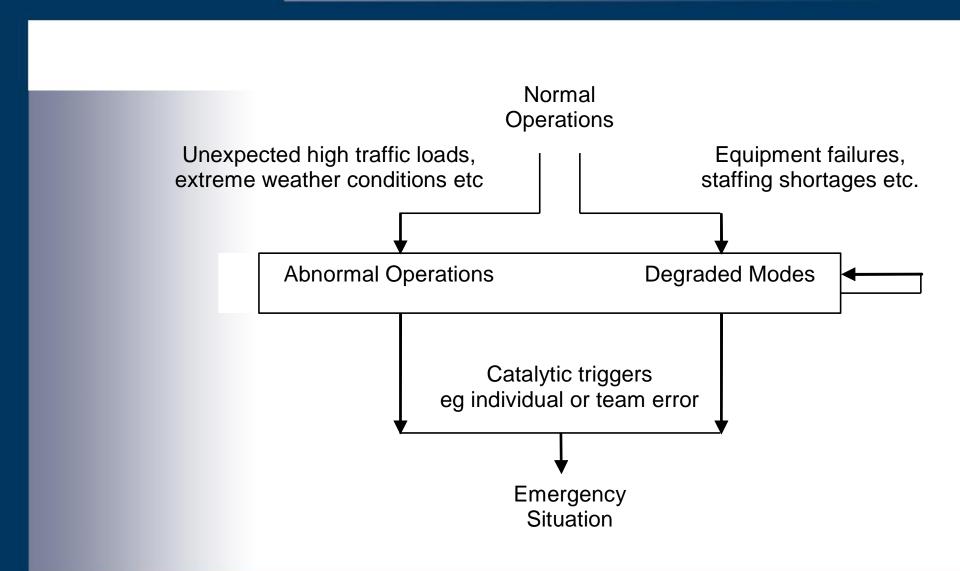
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What are Degraded Modes







- Staff struggle to maintain levels of service.
- Software failures force ad hoc solutions:
 - violate safety requirements;
 - Not supported by risk assessments.
- Lead to major failures if not addressed.



UPS Case Study



- Power Supply Station near ACC:
 Transformer and Generator.
- PS Switching boxes in ACC.
- Equipment installed 30 years ago:
 Procure new kit.
- Installation affects comms ACC/PS



Anatomy of the Incident (1)



14:25 UTC: Alarm Remote Control Unit In PS Station from UPS in ACC.

• Technician to ACC, checks UPS:

1. Warning on UPS display:

<Power Supply is out of tolerance >

- 2. UPS operates on battery supply
- 3. UPS autonomy 13 minutes



Anatomy of the Incident (2)

14:30: Technician returns to PS Station.

- Informs Technical Supervisor about problem
- Calls Head of department is not accessible.

14:32: In ACC again, Technician detects

- UPS autonomy 6 minutes
- Makes erroneous decision to switch PS to 2nd UPS;
- Switches 1st UPS to bypass configuration
- Generator voltage direct to Users, no stabilization;
- Under voltage but no over voltage protection.



Anatomy of the Incident (4)

Time Destination
IST45==CANCEULED====
IS#SO##CANCELLED####
16:00==CANCELLED====
16x00==CANCELLED====
16:00 CANCELLED
16x10##CANCELLED####
16:10 CANCELLED
I6=10==CANCELLED===
16:15=CANCELLED
16:20 CANCELLED
16:30 CANCELLED
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16:30 CANCELLED
16:40 CANCELLED
16:40 CANCELLED
16:40 CANCELLED
16:50 CANCELLED
16:50 CANCELLED

14:35 UTC - In a few minutes collapse of:

- three quarters of Radar Data Displays,
- one half of Flight Data Displays,
- all radar inputs in DPS,
- Controller Working Positions for Voice Comms
- and AFTN connection with ARO & NOTAM.

14:40 UTC - Technical Supervisor tells ATC Supervisor needs 30 minutes.

14:45 UTC - ATC SUP decides to close FIR, CFMU told traffic is zero.



CONTENTS

		Page
1.	Background Information	1
2.	Contingency Arrangements in Place	1
3.	Arrangements in place with the System Supplier to provide support	2
4.	Explanation of the problems which led to the malfunction	2
5.	Measures taken to rectify the problem	4
б.	Details of any Safety Issues Arising	6
7.	Level of Communications between the IAA, the Airlines and Dublin Airport Authority (DAA)	б
8.	Observations	7



REPORT OF THE IRISH AVIATION AUTHORITY

INTO THE ATM SYSTEM MALFUNCTION AT DUBLIN AIRPORT

19th September 2008



Dublin Airport Overview

Busiest period of the year.



- Initial hardware failure:
 - Poor quality of service from LAN;
 - Slows flight data processing system.
- ATCOs cannot access data on radar targets:
 including aircraft identification and type data.
- Capacity restrictions for safety reasons.



Dublin Airport - Contracting



- ATM system provided by contractor:
 - maintained under annual service contract;
 - provide both hardware and software support;
 - On-site support for diagnosis and debugging.
- General question for SESAR?
 - ANSPs rely on subcontractors:
 - key areas of technical support ;
 - 'it will take another 30 minutes...'
 - Is outsourcing a form of de-risking?



Secondary Response

- ANSPs engineering staff correct symptoms;
 Cannot identify root causes of the problem.
- Problem stemmed from double failure:
 - triggered by a faulty network interface card;
 - flooded network with spurious messages.
- Symptoms of the fault were masked;
 - recovery mechanisms in Local Area Network;
 - hard for engineers to identify component failure.



The Real Impact



"The problem here is that you have an autonomous semi-state monopoly which doesn't care about its customers or the disruption to passengers,"



The Real Impact



- "The problem here is that you have an autonomous semi-state monopoly which doesn't care about its customers or the disruption to passengers,"
- "Send the buggers to Shannon, if it was a commercial company they would have done so,"



The Real Impact



- "The problem here is that you have an autonomous semi-state monopoly which doesn't care about its customers or the disruption to passengers,"
- "Send the buggers to Shannon, if it was a commercial company they would have done so,"
- "They're not on top of the job.
 We're talking about 25 arrivals and departures per hour. The air traffic controllers should be capable of handling this volume of flights".





Europe is Not Alone





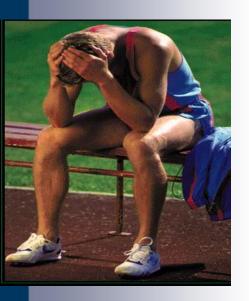
June 2007



- Atlanta FDPS System software bug;
 - Switch data rate configuration error (again).
- Use of fallback system in Salt Lake City:
 Cascading failure cannot cope with demand.
- ATCOs enter flight data manually;
 - Cannot cope with backlog, knock-on delays.
- 12 hours to diagnose problem;
 - 6 more to catch up with backlog eg New York.



August 2008 and November 2009



- August 2008:
 - Software failure in Atlanta again.
 - Processes flight plans for Eastern US.
 - 566 flight delays+
- Press, media and political outrage....
- GAO reports into ATM service provision.





Fault stems from Los Angeles:

- Route map error on a new router installed to replace an older router version
- Routing error affects comms with Atlanta
- Also affects comms with 21 regional radar centers
- Impacted nationwide network supporting air traffic control automation systems
 - 4 hours to diagnose, 12+ to restore support
 - ATCOs enter flight plans manually (workload)
 - Effects exacerbated by bad weather e.g., Chicago
 - As a result of this failure, a second routing domain was established for the traffic



- "Sisters Sharon Walker and Sheila James were taking their elderly mother to see their sister in St. Louis. Their 09.30 flight was delayed until 16:00..."
- "Sen. Charles Schumer said the country's aviation system is 'in shambles'...'the FAA needs to upgrade the system, these technical glitches that cause cascading chaos across the country are going to become a very regular occurrence...'"





April 2010



- \$2.1 Billion upgrade by Dec 2010:
 - En Route Automation Modernization.
- Faults lead to 'missing' flight plans;
 - Other aircraft change identity in flight;
 - Again cannot transfer flight data to Atlanta etc.
 - Undermines ATCO confidence in system;
 - 'fallback' original 20 year old IBM system
 - IBM contract expired, uses Jovial rarely used.
- Test deployment to Salt Lake City:
 - FAA spend \$14 million, still not working.
 - Salt Lake City simple compared to Chicago...



Potential Solutions?











"The Risk Assessment Blind Spot"

NOT MEASUREMENT SENSITIVE

MIL-STD-882D 10 February 2000

SUPERSEDING MIL-STD-882C 19 January 1993

DEPARTMENT OF DEFENSE STANDARD PRACTICE FOR SYSTEM SAFETY



AMSC N/A

AREA SAFT



MIL-STD 882D

	Severity of Occurrence						
Frequency of Occurrence (over the life of an item)	CATASTROPHIC (I)	CRITICAL (II)	MARGINAL (III)	NEGLIGIBLE (IV)			
FREQUENT (A) P > 10 ⁻¹	I-A	II-A	III-A	IV-A			
PROBABLE (B) 10 ⁻¹ > P > 10 ⁻²	I-B	II-B	III-B	IV-B			
OCCASIONAL (C) 10 ⁻² > P > 10 ⁻³	1-0	II-C	Ш-С	IV-C			
REMOTE (D) 10 ⁻³ > P > 10 ⁻⁶	I-D	II-D	III-D	IV-D			
IMPROBABLE (E) 10 ⁻⁶ > P	I-E	II-E	III-E	IV-E			

- 1. Document the approach:
- 2. Identify potential system hazards:
- 3. Assess severity and probability:
- 4. Identify mitigation measures:
- 5. Implementation of mitigation
- 6. Verify intended risk reduction:
- 7. Communicate residual risks:
- 8. Risk management after deployment;





• Haddon-Cave report:

"If risk assessment has been conducted with proper skill, care and attention, the catastrophic fire risk ... would have been spotted".

• Risk assessment:

- no substitute for 'sound judgement'.
- "incompetence, complacency, cynicism".
- Documentation overwhelming;
- Many trivial or irrelevant failure modes;
- Few combined failures across functions;
- Most help for large-scale procurements.



- Techniques to address operational risk:
 - Low cost, approximations, rules of thumb;
 - Where necessary should trigger HAZOPS etc.

"When engineering analysis and risk assessments are condensed to fit on a standard form or overhead slide, information is inevitably lost".

- On the other hand:
 - You cannot capture everything...
 - Limited time, limited training, present threats.



Composite Risk Management

CRM			HAZARD PROBABILITY				
MA	ATRDX		Frequent A	Likely B	Occasional C	Seldom D	Unlikely
È	Catastrophic	1	EXTRE HIGH	MELY	HIGH		
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Composite Risk Management

CRM			HAZARD PROBABILITY				
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Composite Risk Management

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Composite Risk Management

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Composite Risk Management



Composite Risk Management



Composite Risk Management

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Composite Risk Management



Composite Risk Management

CRM MATRIX	HAZARD PROB Frequent Likely Occasiona A B C	ABILITY Seldom Unlikely D E
Catastrophic Critical II Marginal III Negligible IV	EXTREMELY HIGH MODERATE	LOW

Composite Risk Management

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Composite Risk Management

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Composite Risk Management

CRM MATRIX	H. Frequent	AZARD I Likely Oc B			
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ROTARY-WING RIS	ASSESSMENT MATRIX	ROTARY-WING RISK	ASSESSMENT MATRIX
1. SUPERVISION (Risk Value/Mission) CMD/CONTROL VALUE TACTICAL DAY/NIGHT DAY/NIGHT Parent Unit 1 1 Attached 2 3 4	2. PLANNING (Risk Value/Time) GUIDANCE IN-DEPTH ADEQUATE MINIMAL Vague 3 4 5 Implied 2 3 4 Specific 1 2 3	12. NVG CREW SEL/PC (Total NVG Time) >150 <150 <100 <50 <25 1 2 3 4 5	13. NVG CREW SEL/PI (Total NVG Time) >150 <150 <100 <50 <25 1 2 3 4 5
Attached 2 3 4 3. CREW SEL/PC (Risk Value/Fit Hrs) TIME IN TOTAL TIME AO* >2000 <2000	Specific 1 2 3 4. CREW SEL/PI (Risk Value/Fit Hrs) TIME IN TOTAL TIME AO* >2000 <1000	14. NVG CREW SEL/ADD (Total NVG Time) >150 <150 <100 <50 <25 1 2 3 4 5	15. PERCENT OF ILLUMINATION (NVG) 100-80 79-60 59-40 30-23 <23 1 2 3 4 5
<pre><25 3 4 5 6 >50 2 3 4 5 >50 1 2 3 4</pre>	<25 3 4 5 6 >50 2 3 4 5 >50 1 2 3 4 5	16. MOON ANGLE (NVG) 90-70 69-50 49-30 <30 0 1 2 3	17. ADDITIONAL RISK FACTORS (NVG)
5. CREW SEL/ADD (Risk Value/Fit Hrs) TIME IN TOTAL TIME AO* >2000 <1000	6. ALL CREW MEMBERS ARE CREW COORDINATION TRAINED No +2 Yes 0 8. CREW ENDURANCE (Risk Value/Fit Hrs) QUALITY >8 HRS 6-8 HRS <6 HRS	RISK VALUES: DAY/NIGHT MISSIONS 1. Supervision 2. Planning 3. Crew Selection/PC 4. Crew Selection/PI 5. Crew Selection/Add 6. Crew Coordination Trained	RISK VALUES: DAY/NIGHT MISSIONS 12. NVG Crew Selection/PC 13. NVG Crew Selection/PI 14. NVG Crew Selection/Add 15. Illumination 16. Moon Angle (NVG) 17. Additional Risk Factors
UNIT MISSION ARE SOFFOR TED BY THE UNIT MISSION ESSENTIAL TASK LIST (METL) Yes 0 No 5# #Requires bn cdr approval.	OF REST Field 2 6 10 Garrison 1 4 10 Add 2 for missions flown during the last half of the duty day.	7. METL Task	TOTAL NVG MISSIONS
9. COMPLEXITY TYPE OF MISSION(Value/Condition) VMCIMCDNHOODMultiship264Sling load235Stabo/Rappel124Terrain Flt132Paradrop22NARoutine122NOE284	10. WEATHER** (Risk Value/Ceiling/Visibility) <1000/3	COMPUTATIONS D _P Y/NIGHT MISSIONS Low Risk <16 Medium Risk 16-28* High Risk >29** * Medium-risk missions require approval of the company ** High-risk missions require approval of the battallon co *** Extremely high-risk missions require approval of the	ommander.
MTP 3 5 NA NA Maint Recovery 3 5 NA NA ADDITIONAL COMMENTS * Area of operations. ** Visibility values are given in miles.		ADDITIONAL COMMENTS •US Army TC 1	1-210



Wider Applications: MATS Forms...

Regulatory Change Management Coordination Form

Note: The Regulator's representative should complete this form and send it back to the Quality and Safety Management section before the process of change is initiated. This form indicates clearly the level of information or involvement expected by the regulator in the change being proposed by the ANSP. This process is applicable only to Major Changes proposed by the ANSP.

Type of Change:

 People	Equipment	Procedures
Operational	Technical	Other

Brief Description of the Change	
The Change process is expected to be initiated on:	

The Regulator after analysing the presented change proposal requests:

Name Date Si	gn (<u>for</u> AN SP)
Name Date Si	gn (<u>for</u> Regulator)
More information	Þ
Notto be involved and the ANSP may proceed	
To be given a copy of the final document of the change	
To be involved and invited for the safety assessment	

- Cover Title Page Abstract
 - Contents
 - 🔄 Figures
 - Abbreviations
 - Executive Summary
- Requirements for EMS Operations Conducted Without Patients On Board
- Aviation Flight Risk Evaluation Programs for EMS Operations
- ł
- Flight Dispatch Procedures
- Use of Technology to Assist in EMS Flight Operations
- ₽-┣
- Conclusions



Recommendations



Board Member Statement



Appendixes

Special Investigation Report on Emergency Medical Services Operations



Aviation Special Investigation Report NTSB/SIR-06/01

PB2006-917001 Notation 4402E



National Transportation Safety Board Washington, D.C.



NTSB Risk Assessment Matrices

	o occorriganio	reduction managements was or the system.
	Critical	Results in severe injury and/or major system damage.
	Marginal	Results in minor injury and/or minor system damage.
	Negligible	Results in less than minor injury and/or less than minor system damage.
ATRIX		
Critical Catastrophic		Likelihood Scale Definitions

	Likelihood Scale Definitions					
Frequent	Frequent Individual Likely to occur often.					
	Fleet	Continuously experienced.				
Probable	Individual	Will occur several times.				
	Fleet	Will occur often.				
Occasional	Individual	Likely to occur sometime.				
	Fleet	Will occur several times.				
Remote	Individual	Unlikely to occur, but possible.				
	Fleet	Unlikely, but can reasonably be expected to occur.				
Improbable	Individual	So unlikely, it can be assumed it will not occur.				
	Fleet	Unlikely to occur, but possible.				

Severity Scale Definitions

Catastrophic Results in fatalities and/or loss of the system

	Severity	SSESSMENT	MATRIA	
Likelihood	Negligible	Marginal	Critical	Catastrophic
Frequent				
Probable				High
Occasional			Serious	
Remote		Medium	1	
Improbable	Low			



EXAMPLE 2A. RISK ASSESSMENT MATRIX: NIGHT OPERATIONS

RISK ASS	RISK ASSESSMENT MATRIX: NIGHT OPERATIONS				
Use this tool to assess the potenti	al for links in the s	afety chain.			
		Applicable We	ather for Flight	_	
Apply Operational Factors	WEATHER Wdl Above Minimums and Stable	CEILING Within 1000' of Minimums	VISIBILITY Within 3 mi. of Minimums	CEILING & VIS Within 3 mi. and 500° of Mina.	
NIGHT					
Normal ops AIRCRAFT					
Performance near max Back-up or different A/C MEL items					
ENVIRONMENTAL					
Extreme heat or cold High winds Storms in area					
FATIGUE					
Late in shift? Consecutive shifts?					

Risk Assessment Value:

Normal Ops
Caution
Extreme Caution
Critical Safety Decision Required



EXAMPLE 2B. RISK ASSESSMENT MATRIX: DAY OPERATIONS

RISK ASSESSMENT MATRIX: DAY OPERATIONS				
Use this tool to assess the potential for links in the safety chain.				
	Applicable Weather for Flight			
Apply Operational Factors	WEATHER Well Above Minimums and Stable	CEILING Within 1000° of Minimums	VISIBILITY Within 3 mi. of Minimums	CEILING & VIS Within 3 mi. and 500' of Mins.
DAY				
Normal ops				
AIRCRAFT				
Performance near max				
Back-up or different A/C MEL items				
ENVIRONMENTAL				
Extreme heat or cold				
High winds				
Storms in area				
FATIGUE				
Late in shift? Consecutive shifts?				

Risk Assessment Value:

Normal Ops
Caution
Extreme Caution
Critical Safety Decision Required



Rapid Risk Assessment

8/1/05

N 8000.301 Appendix 1

APPENDIX 1. EXAMPLES OF PROCEDURE-WEIGHTED RISK ASSESSMENT AND MANAGEMENT PROCESSES

EXAMPLE 1. GO/NO-GO DECISION MATRIX

STATIC RISK FACTORS		SCORE
< 6 mos. on Current Job	+1	
<1 yr. in EMS	+1	
< 200 hrs. in Type	+1	
> 500 hrs. In Type	-1	
Last Flight > 30 Days	+1	
Last Night Flight > 30 Days (night requests only)	+1	
6 mos. Since Check Ride	+2	
Cockpit Not Configured for Inadvertent IMC	+1	
Navigation or Radio Item on MEL	+1	
Back-up Aircraft	+1	
Newly-installed Equipment (i.e., satellite phone, avionics, GPS)	+1	
Night Vision Goggles (NVG) Equipped	-1	
< 3 NVG Flights in the Last 120 Days	+1	
Medical Crew < 1 yrs. Experience (both crewmembers)	+1	
IFR Program	-4	
VFR Program	+1	
External Stresses (divorce, illness, family/work issues/conflicts)	+1	

Total Static Score

DYNAMIC RISK FACTORS

DINAMIC RISK FACTORS		
Celling within 200' of Program Minimums	+1	
Visibility within 1 Mile of GOM Minimums	+1	
Precipitation with Convective Activity	+1	
Convective Activity with Frontal Passage	+1	
Deteriorating Weather Trend	+1	
High Wind or Gust Spread Defined by Operations Manual	+2	
Modera te Turbule nce	+2	
Temperature/Dew Point < 3 Degrees F	+1	
Forecast Fog, Snow, or Ice	+2	
Weather Reporting at Destination	-1	
Mountainous or Hostile Terrain	+1	
Class B or C Airspace	+1	
Ground Reference Low	+1	
Ground Reference High	-1	
NightFlight	+1	
90% of Usable Fuel Required (not including reserve)	+1	
Flight Turned Down by Other Operators Due to Weather (if known)	+4	
Control Measures		
Delay Flight	-1	
Avoid Mountainous/Hostile Terrain	-1	
Utilize Pre-Designated LZs for Scene Requests	-1	
Plan Alternate Fuel Stop	-1	
Familiarization Training (self-directed)	-1	

EXAMPLE 1. GO/NO-GO DECISION MATRIX (Continued)

Grand Total of Static and Dynamic Scores				
RISK CATEGORY	COLOR		EOC ACTION	TOTAL
NORMAL		GREEN	Pilot Approval	0 - 14
FLIGHT MANAGER		YELLOW	Call Manager	15 - 18
UNACCEPTABLE		RED	Cancel Flight	19 or Greater

Total Dynamic Score

EXAMPLE 2. ASSESSMENT CHART

1. EXPERIENCE Less than 2 years 2–3 years 4–5 years	+10 +5 +2	
 WEATHER Less than 3,000' – 5 sm (Anywhere on the route) 	+5	
 NIGHT (During any portion of the flight) 	+ 5	
4. NON-LOCAL (Applies to all flights out of defined local flying area) Not local	+4	
New location	+3	
5. EARLY MORNING Flight between 2 a.m. and 5 a.m. (If any portion of the flight to fall in this time window)	+1	
TOTAL		

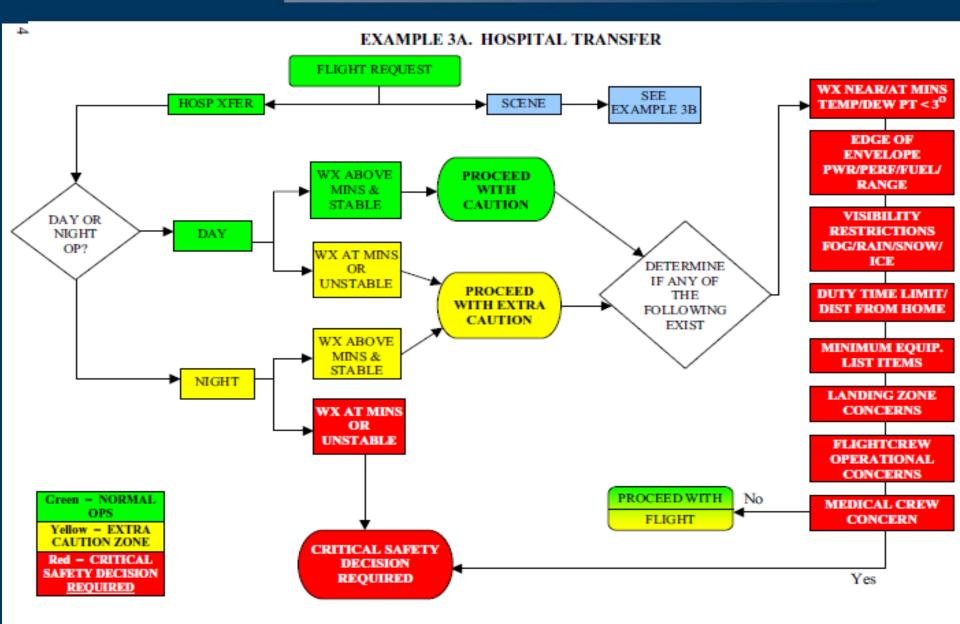
Considerations-

- Have you been to this destination before? How recently?
- 2) What are the weather conditions? How confident are you of the weather along the entire route?
- Is all or any part of this mission going to occur at night? If so, will you have some moonlight?
- 4) Have you thought through the entire mission? That is, can you return as easily as you can get there?
- 5) Are there any problems with the aircraft that may be a factor for this mission?
- 6) How many consecutive shifts have you worked prior to this mission? How much flying have you done during those shifts?
- 7) Do you feel fally rested and capable to accept this mission?
- Do you have any reservations at all with accepting this mission?

A TOTAL of 20 or higher requires greater operational control.



Rapid Risk Assessment





Any Questions?



