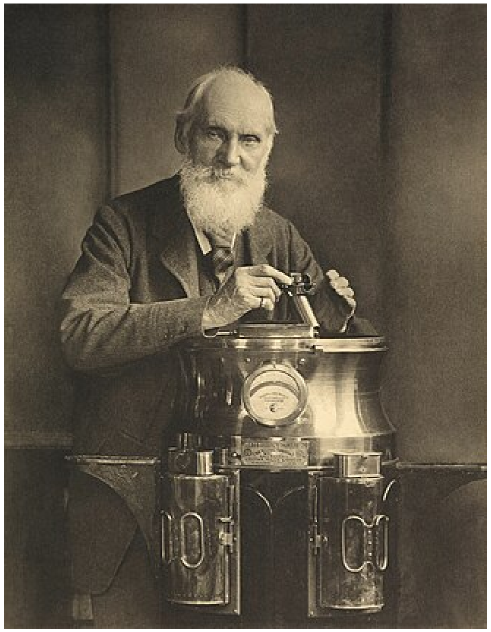
Airlines for America™
We Connect the World

Two Clouds on the Horizon of MSG-4

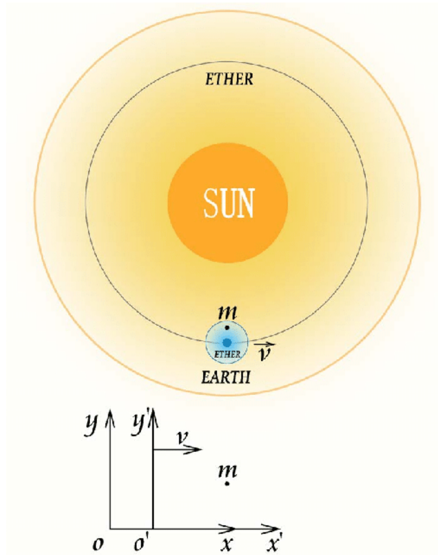
--Why a Safety Envelope for MSG Methodology is Important

Wang Yiping
MSG-X Group, Customer Service Center, COMAC
IMRBPB 2025, Dubai, May 4-9

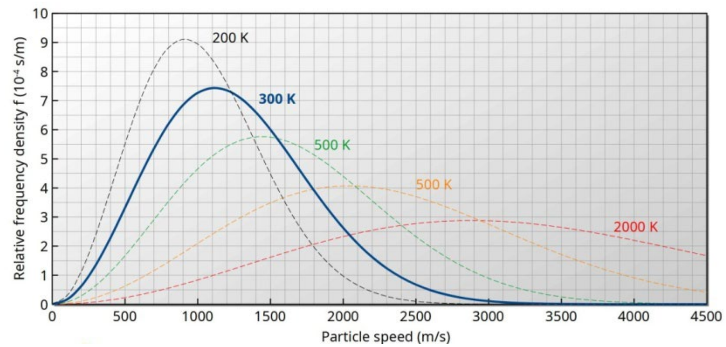
Two Clouds on the Horizon of 19th Century Physics



Lord Kelvin (William Thomson)
1824-1907



The relative motion of the ether with respect to massive objects*



*Maxwell-Boltzmann velocity distribution as a function of temperature**

Airlines for America
We Connect the World

** Pictures are only for brief image of the “ two clouds”*

Two Clouds on the Horizon of MSG-4

- IP 053.

IMRBPB Position:

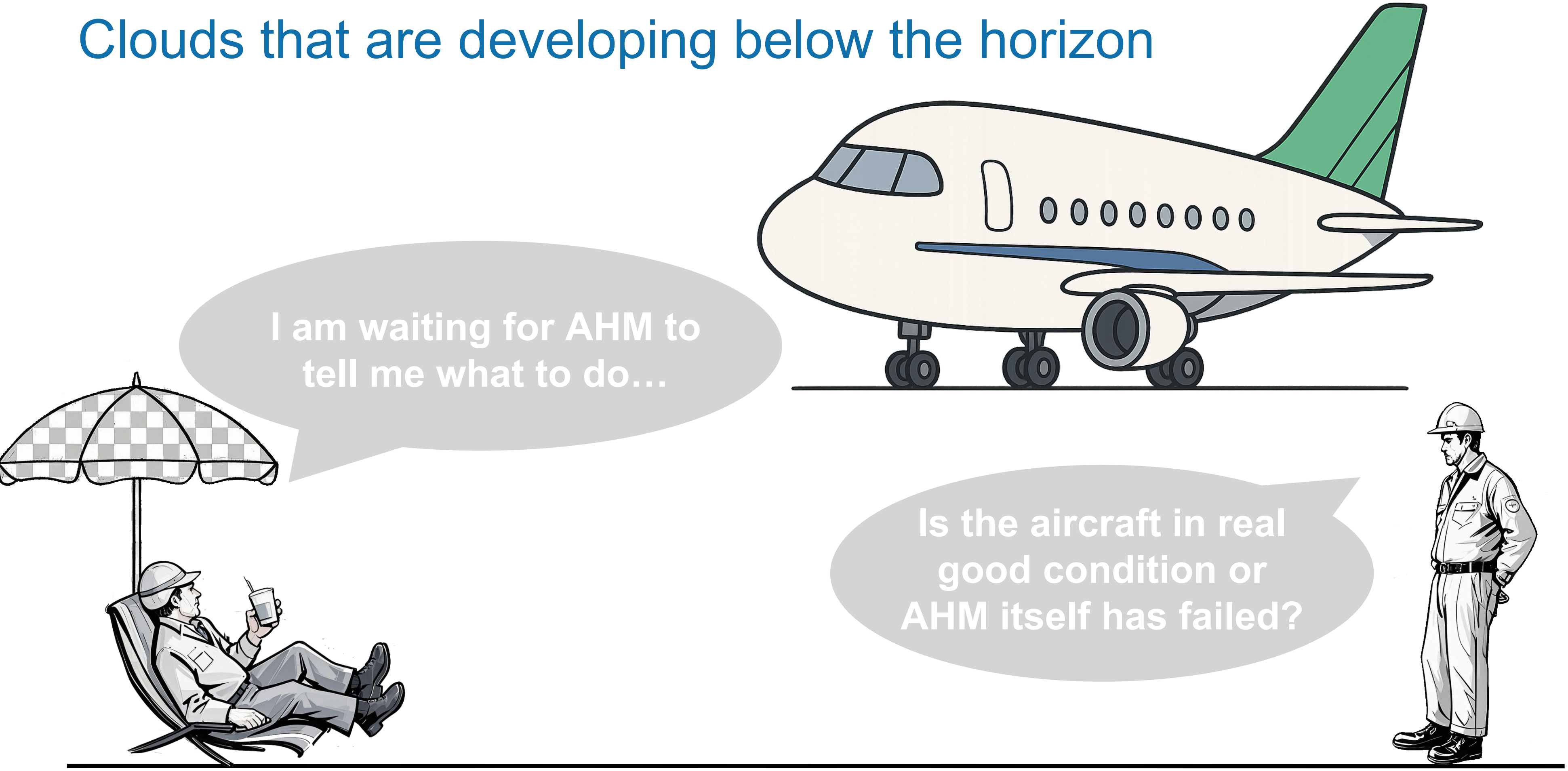
December 2001: It was accepted that subject to adequate justification the Authorities may accept any alternative to MSG-3. However, the onus would be on the applicant to demonstrate that their alternative means of compliance results in an equivalent level of safety. Issue paper closed.

- IP 180.

The references to and use of Aircraft Health Monitoring throughout this section requires the certification of the associated system features by the type certification staff of the Regulatory Authority. The use of AHM is limited to non-safety tasks provided the tasks are not covering CCMRs."

Two Clouds on the Horizon of MSG-4

Clouds that are developing below the horizon



Current Safety Concept Study & Review

Generally, the MSG-3 methodology is reliability centered and relies heavily on experience. Its safety level has not been thoroughly and systematically calculated or evaluated.

Taking system analysis as an example

✈Category 5/8 failure

- ✓ How much impact will the failure have on safety?
- ✓ When one or more tasks are selected based on MSG-3 logic, to what extent does the selected task or tasks improve safety?

Current Safety Concept Study & Review

Any difference between safety in §25.1309 and safety in MSG-3?

Failure Condition vs. Probability
（In AC 25.1309 & AC 25-19）

Failure Condition	Qualitative Probability	Quantitative Probability
Minor	Probable	$P>1 \times 10^{-5}$
Major	Remote	$1 \times 10^{-7} < P \leq 1 \times 10^{-5}$
Hazardous	Extremely Remote	$1 \times 10^{-9} < P \leq 1 \times 10^{-7}$
Catastrophic	Extremely Improbable	$P \leq 1 \times 10^{-9}$

Note:
1. AC 25.1309-1B was formally released on 08/30/2024
2. Amdt. No. 25–152 "System Safety Assessments" was published at 89 FR 68735, Aug. 27, 2024, and was effective on Sept. 26, 2024

Current Safety Concept Study & Review

Any difference between safety in §25.1309 and safety in MSG-3?

Failure Condition vs. Probability
（In AC 25.1309 & AC 25-19）

Failure Condition	Qualitative Probability	Quantitative Probability
Minor	Probable	$P>1 \times 10^{-5}$
Major	Remote	$1 \times 10^{-7} < P \leq 1 \times 10^{-5}$
Hazardous	Extremely Remote	$1 \times 10^{-9} < P \leq 1 \times 10^{-7}$
Catastrophic	Extremely Improbable	$P \leq 1 \times 10^{-9}$

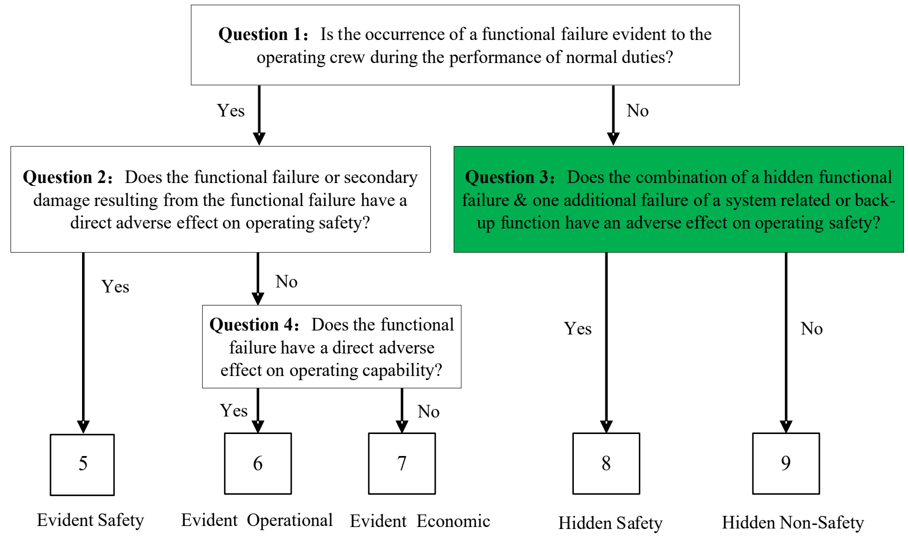
What the safety in §25.1309 ?
Old §25.1309 :"(b) (1) The occurrence of any failure condition which would prevent the continued safe flight and landing of the airplane is extremely improbable, and"
Current *§25.1309 : "(b)(1) Each catastrophic failure condition-(i) Must be extremely improbable; and (ii) Must not result from a single failure."*

Current Safety Concept Study & Review

Any difference between safety in §25.1309 and safety in MSG-3?

Failure Condition vs. Probability
（In AC 25.1309 & AC 25-19）

Failure Condition	Qualitative Probability	Quantitative Probability
Minor	Probable	$P>1 \times 10^{-5}$
Major	Remote	$1 \times 10^{-7} < P \leq 1 \times 10^{-5}$
Hazardous	Extremely Remote	$1 \times 10^{-9} < P \leq 1 \times 10^{-7}$
Catastrophic	Extremely Improbable	$P \leq 1 \times 10^{-9}$



What's the safety in MSG-3?

Question 3: Does the combination of a hidden functional failure & one additional failure of a system related or back-up function have an adverse effect on operating safety?

Potential difference between safety in §25.1309 and safety in MSG-3?

A. Hidden safety in MSG-3 can be No-safety in *§25.1309*

B. Hidden Non-Safety in MSG-3 can be Safety in §25.1309

Airlines for America™
We Connect the World

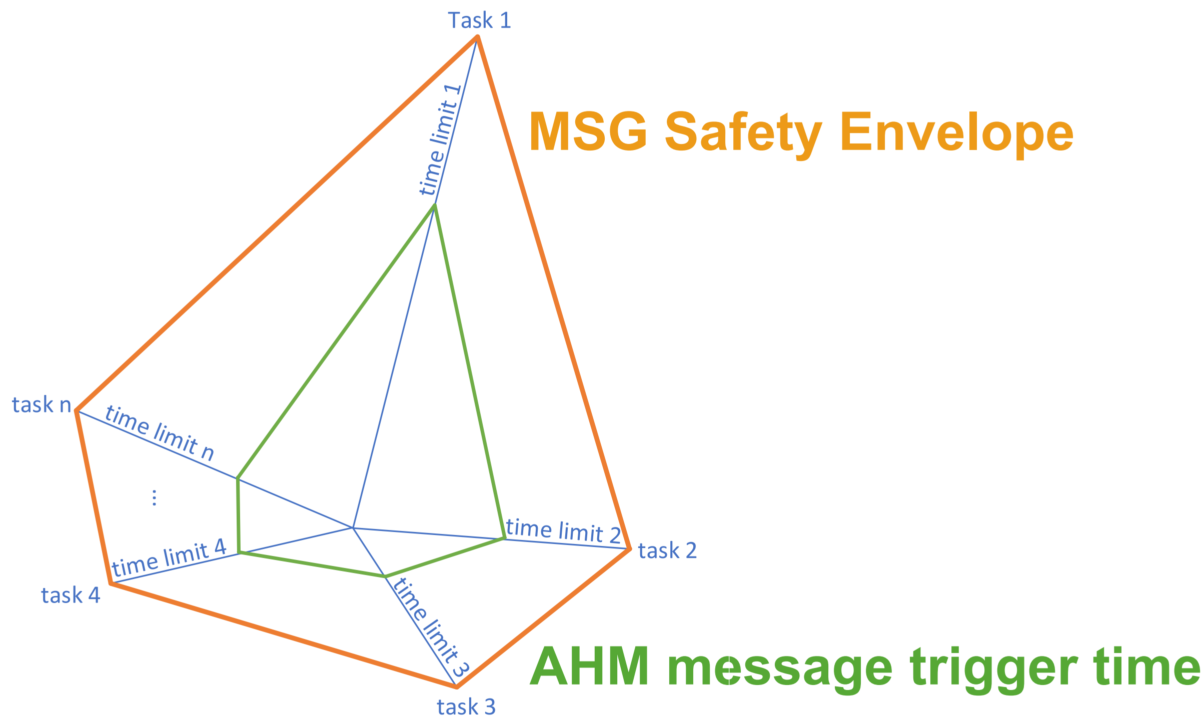
Understanding the Difference

A story from Authority Member: His colleagues from the certification division came over and said to him that AHM had to be officially certified for its use. But when he asked the certification team to join their discussions about AHM and MSG-3, they were like, 'Nah, nah, nah—we’re not jumping into your meeting.' Like it wasn’t their job at all.

Safety Envelope Concept for MSG-4

How about defining and quantifying reliability level and then finding a safety envelope for MSG methodology?

Failure Condition	Reliability Required
Minor	80%
Major	90%
Hazardous	95%
Catastrophic	X

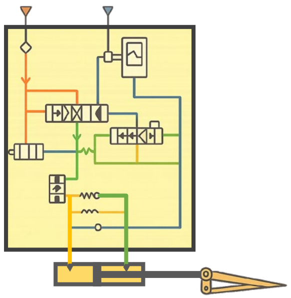


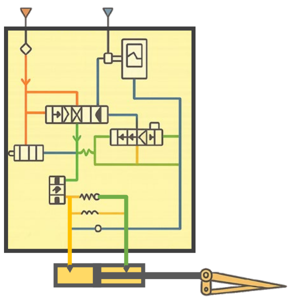
End-to-End Reliability Concept for MSG-4

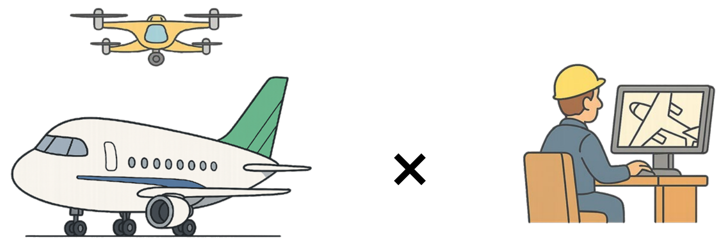
Aircraft Reliability

Task Generation Reliability

Task Accomplishment Reliability



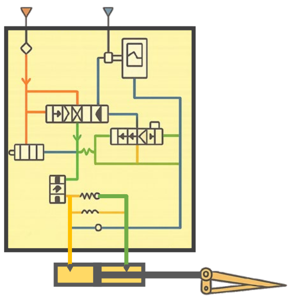


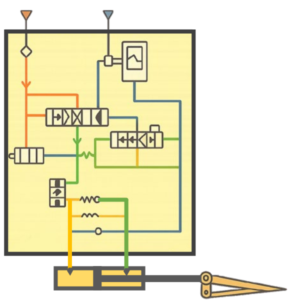


Airlines for America™
We Connect the World

End-to-End Reliability Concept for MSG-4

Aircraft Reliability | Task Generation Reliability | Task Accomplishment Reliability





Airlines for America™
We Connect the World

Safety Envelope for MSG-4
--Case Study

4Provides redundant flutter protection means in the event of an un-powered aileron surface.	4AFails to provide redundant flutter protection means in the event of an un-powered aileron surface.	4A1Loss of redundant for flutter protection. Flutter protection will be provided by remaining actuator.	4A1a Aileron PCU failure (Compensator severe internal/external leakage or jammed, Inlet Check Valve failed, Anti-Cavitation Check Valve failed or Variable Damping Orifice failed, severe external or internal leakage of return relief valve).	Operational check of aileron power control unit compensators Functional check (initiated actuator build in test) of aileron power control units	12000FH 700FH
			4A1b Aileron PCU Attachment failure (excessive wear).	Lubrication of aileron power control unit bearings Functional check of the aileron surface free play	24MO 10000FH
			4A1c Excessive aileron surface hinge bearing wear	Functional check of the aileron surface free play	10000FH

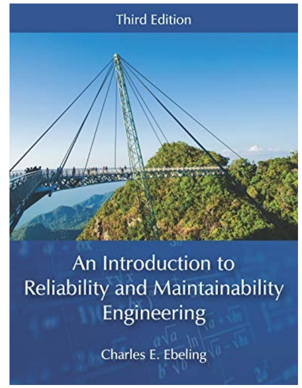
Table Reliability data of LRUs

Item Number	Item Title	MTBF
27-12-01	Aileron PCU	80000FH
57-61-35	Aileron surface hinge assembly	119800FH

Safety Envelope for MSG-4
--Case Study

Assuming an AHM system is designed and it can diagnose/monitor function failure 4A perfectly.

Parameters:
system function failure rate: $\lambda_1(t)$
AHM failure rate: $\lambda_2(t)$
AHM diagnose correctly probability : P_1
Maintenance action correctly executed probability: P_2



Reactive Maintenance(RM)	Preventive Maintenance(PM)	Predictive Maintenance(PdM)
$R(t) = e^{-\int_0^t \lambda_1(t')dt'}$	$R(t) = \left[e^{-\int_0^T \lambda_1(t')dt'}\right]^n e^{-\int_0^\tau \lambda_1(t')dt'}$ *Where t=nT+τ*	↓

$$R(t) = e^{-\int_0^t [\lambda_1(\tau)(1-P_1P_2)+\lambda_2(\tau)]d\tau} + \int_0^t \lambda_2(s)\, e^{-\int_0^s [\lambda_1(\tau)(1-P_1P_2)+\lambda_2(\tau)]d\tau} e^{-\int_s^t \lambda_1(\tau)d\tau} ds$$

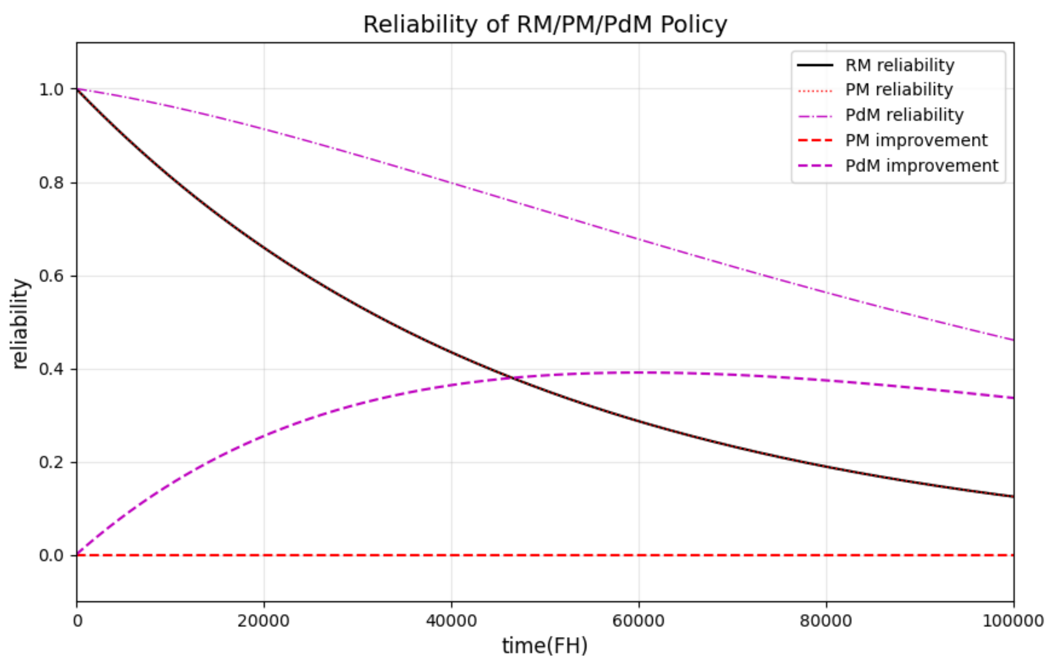
Safety Envelope for MSG-4
--Case Study

system function failure rate: $\lambda_1(t) = \lambda_1$
AHM failure rate: $\lambda_2(t) = \lambda_2$
AHM diagnose correctly probability : P_1
Maintenance action correctly executed probability: P_2

Exponential-Exponential Distribution

λ_1=1/ 80000FH+1/119800FH
λ_2= 1/100000FH
P_1 =0.9
P_2=0.95
T=120000FH

Reacitve Maintenance(RM)	Preventive Maintenance(PM)	Predictive Maintenance(PdM)
$R(t) = e^{-\lambda_1 t}$	$R(t) = e^{-\lambda_1 t}$	$R(t) = e^{-[\lambda_1(1-P_1P_2)+\lambda_2]t} + \frac{\lambda_2}{\lambda_1 P_1 P_2 - \lambda_2}\left(e^{-[\lambda_1(1-P_1P_2)+\lambda_2]t} - e^{-\lambda_1 t}\right)$



Airlines for America™
We Connect the World

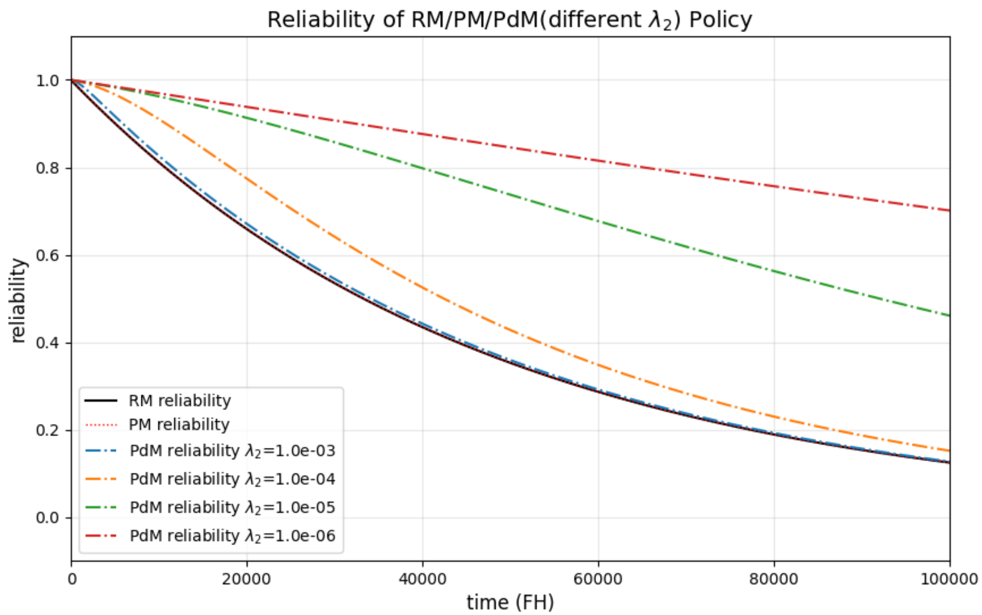
Safety Envelope for MSG-4
--Case Study

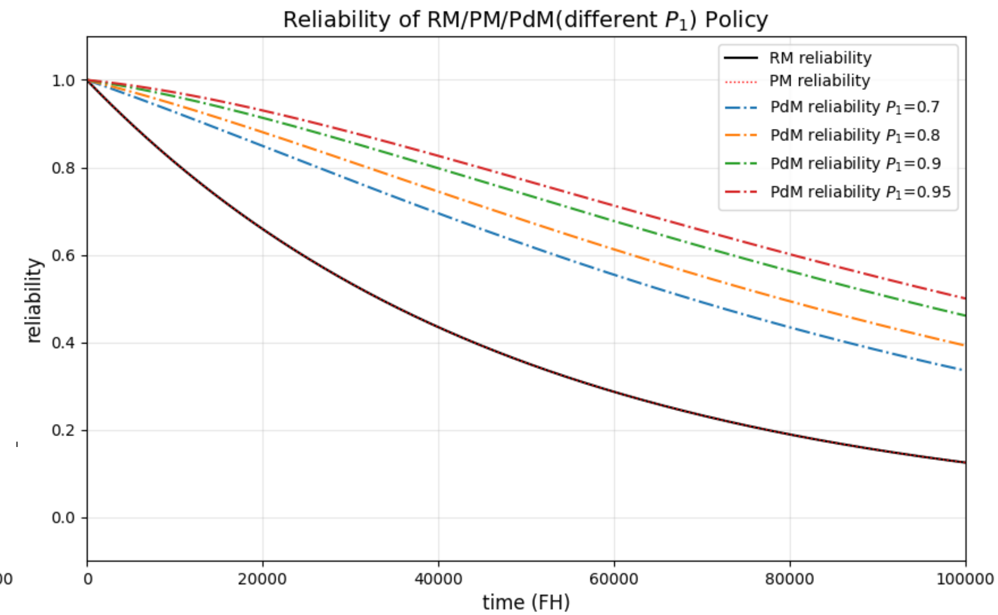
system function failure rate: $\lambda_1(t) = \lambda_1$
AHM failure rate: $\lambda_2(t) = \lambda_2$
AHM diagnose correctly probability : P_1
Maintenance action correctly executed probability: P_2

Exponential-Exponential Distribution

λ_1=1/ 80000FH+1/119800FH
λ_2= varies (left)
P_1 =varies (right)
P_2=0.95
T=120000FH

Reacitve Maintenance(RM)	Preventive Maintenance(PM)	Predictive Maintenance(PdM)
$R(t) = e^{-\lambda_1 t}$	$R(t) = e^{-\lambda_1 t}$	$R(t) = e^{-[\lambda_1(1-P_1P_2)+\lambda_2]t} + \frac{\lambda_2}{\lambda_1 P_1 P_2 - \lambda_2}\left(e^{-[\lambda_1(1-P_1P_2)+\lambda_2]t} - e^{-\lambda_1 t}\right)$





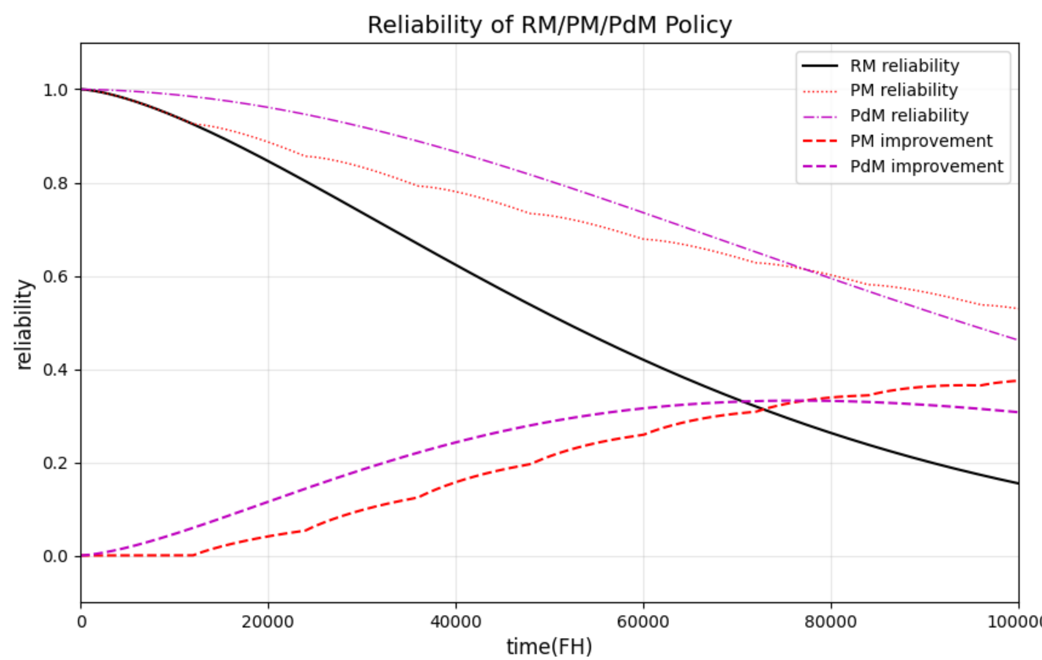
Safety Envelope for MSG-4 --Case Study

system function failure rate: $\lambda_1(t) = \frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1}$
AHM failure rate: $\lambda_2(t) = \lambda_2$
AHM diagnose correctly probability : P_1
Maintenance action correctly executed probability: P_2

Weibull-Exponential Distribution

η=65950FH, β=1.2
λ_2= 1/100000FH
P_1 =0.9
P_2=0.95
T=12000FH

Reactive Reliability(RM)	Preventive Maintenance(PM)	Predictive Maintenance(PdM)
$R(t) = e^{-(t/\eta)^\beta}$	$R(t) = e^{-n(T/\eta)^\beta} \cdot e^{-(\tau/\eta)^\beta}$ Where t=nT+τ	$R(t) = e^{-(1-P_1P_2)(t/\eta)^\beta} e^{-\lambda_2 t} + \lambda_2 e^{-(t/\eta)^\beta} \int_0^t e^{-(\lambda_2 t' - P_1P_2(t'/\eta)^\beta)} dt'$



Airlines for America™
We Connect the World

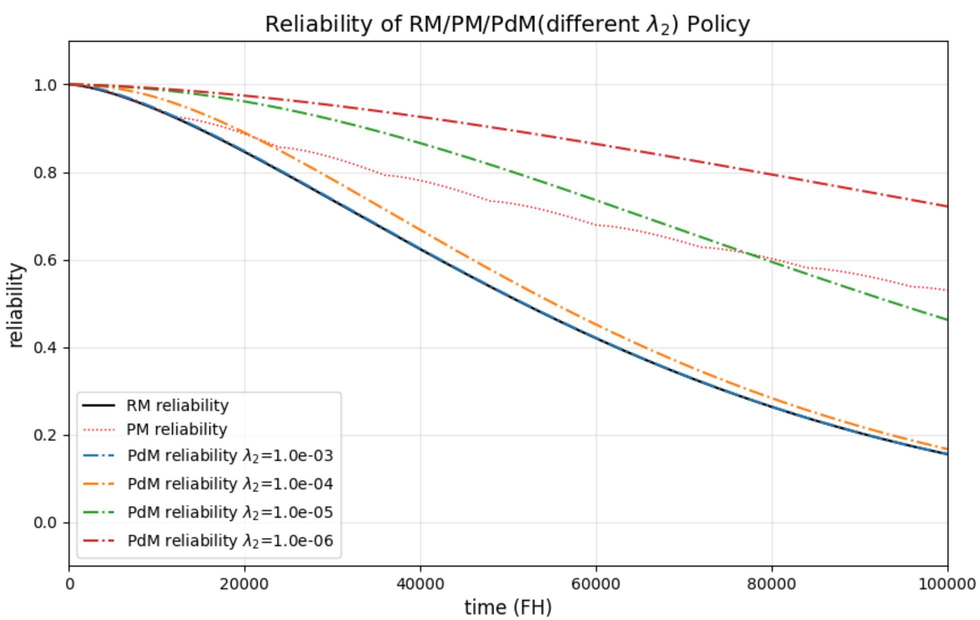
Safety Envelope for MSG-4
--Case Study

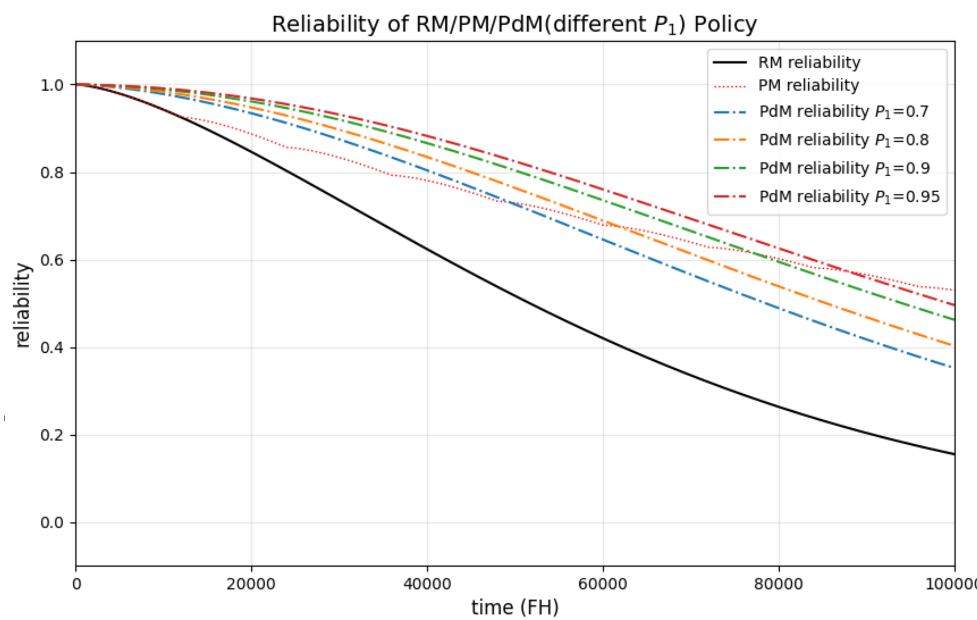
system function failure rate: $\lambda_1(t) = \frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1}$
AHM failure rate: $\lambda_2(t) = \lambda_2$
AHM diagnose correctly probability : P_1
Maintenance action correctly executed probability: P_2

Weibull-Exponential Distribution

η=65950FH, β=1.2
λ_2= varies (left)
P_1 =varies (right)
P_2=0.95
T=12000FH

Reactive Reliability(RM)	Preventive Maintenance(PM)	Predictive Maintenance(PdM)
$R(t) = e^{-(t/\eta)^\beta}$	$R(t) = e^{-n(T/\eta)^\beta} \cdot e^{-(\tau/\eta)^\beta}$ Where $t=nT+\tau$	$R(t) = e^{-(1-P_1P_2)(t/\eta)^\beta} e^{-\lambda_2 t} + \lambda_2 e^{-(t/\eta)^\beta} \int_0^t e^{-(\lambda_2 t' - P_1P_2(t'/\eta)^\beta)} dt'$





Safety Envelope for MSG-4
--Case Study

system function failure rate: $\lambda_1(t) = \frac{\beta_1}{\eta_1}\left(\frac{t}{\eta_1}\right)^{\beta_1 - 1}$

AHM failure rate: $\lambda_2(t) = \frac{\beta_2}{\eta_2}\left(\frac{t}{\eta_2}\right)^{\beta_2 - 1}$

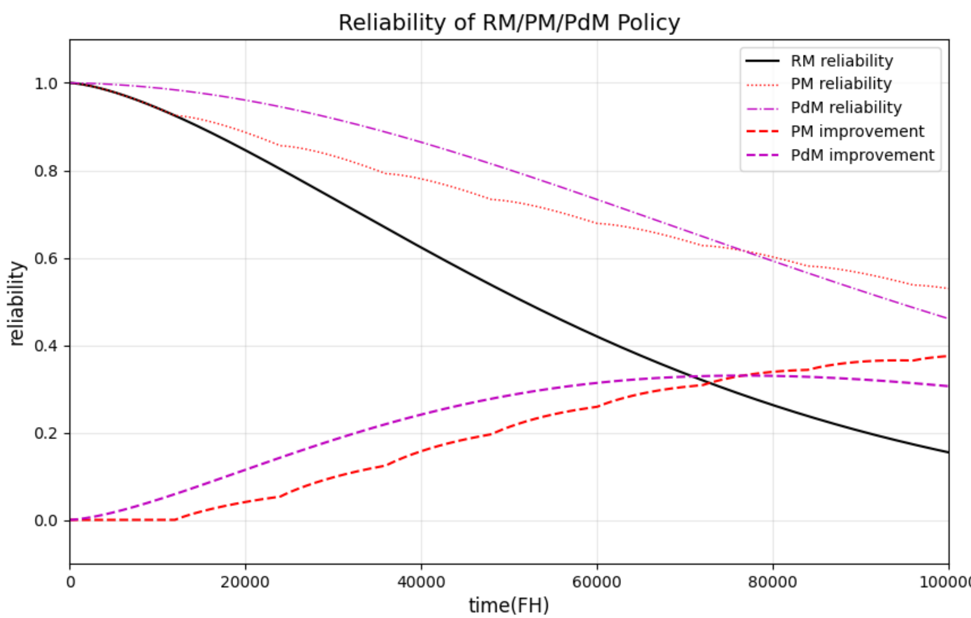
AHM diagnose correctly probability : P_1

Maintenance action correctly executed probability: P_2

Weibull-Weibull Distribution

η_1= 65950FH, β_1=1.5,
η_2= 100000FH, β_2=0.98,
P_1 =0.9
P_2=0.95
T=12000FH

Reacitve Reliability(RM)	Preventive Maintenance(PM)	Predictive Maintenance(PdM)
$R(t) = e^{-\left(\frac{t}{\eta_1}\right)^{\beta_1}}$	$R(t) = e^{-n\left(\frac{T}{\eta_1}\right)^{\beta_1}} \cdot e^{-\left(\frac{\tau}{\eta_1}\right)^{\beta_1}}$ *Where t=nT+τ*	$R(t) = e^{-(1-P_1P_2)\left(\frac{t}{\eta_1}\right)^{\beta_1} - \left(\frac{t}{\eta_2}\right)^{\beta_2}} + e^{-\left(\frac{t}{\eta_1}\right)^{\beta_1}} \int_0^t \frac{\beta_2}{\eta_2}\left(\frac{t'}{\eta_2}\right)^{\beta_2 - 1} e^{-\left(\frac{t'}{\eta_2}\right)^{\beta_2} + P_1P_2\left(\frac{t'}{\eta_1}\right)^{\beta_1}} dt'$



Safety Envelope for MSG-4 --Case Study

system function failure rate: $\lambda_1(t) = \frac{\beta_1}{\eta_1}\left(\frac{t}{\eta_1}\right)^{\beta_1 - 1}$

AHM failure rate: $\lambda_2(t) = \frac{\beta_2}{\eta_2}\left(\frac{t}{\eta_2}\right)^{\beta_2 - 1}$

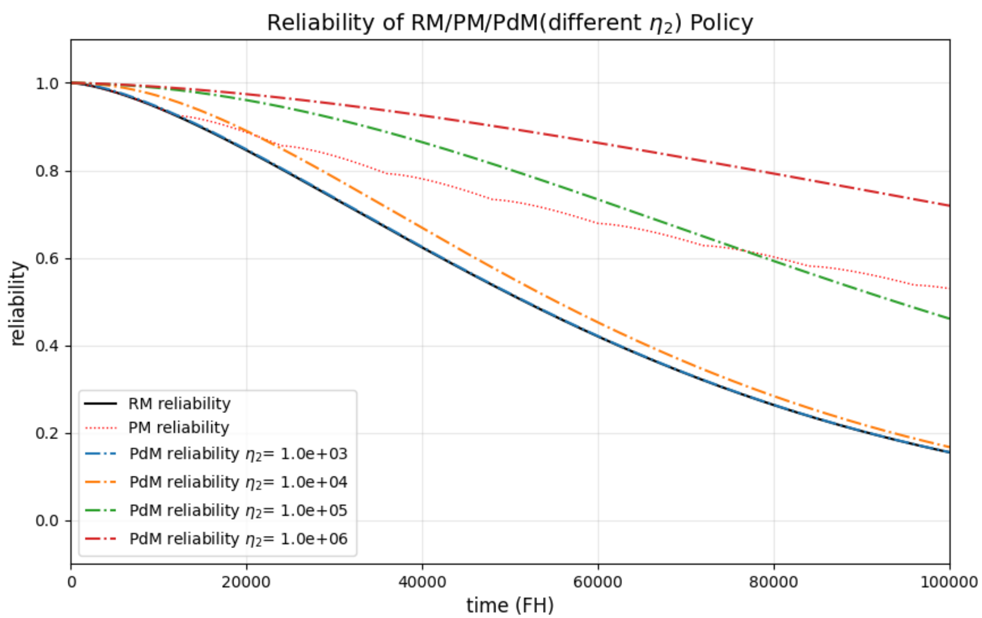
AHM diagnose correctly probability : P_1

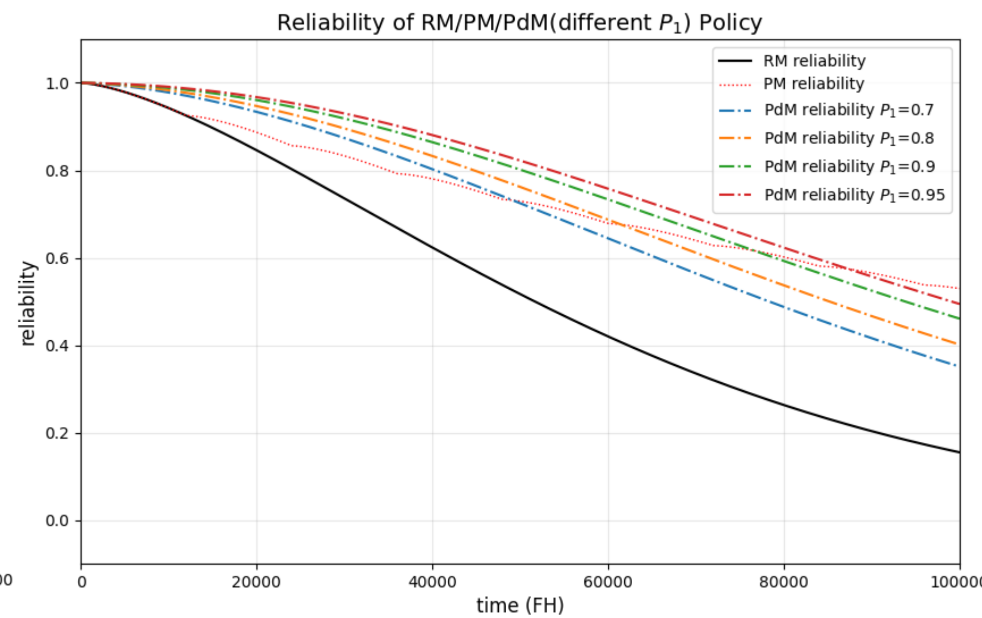
Maintenance action correctly executed probability: P_2

Weibull-Weibull Distribution

η_1= 65950FH, β_1=1.5,
η_2= varies (left), β_2=0.98,
P_1 =varies (right)
P_2=0.95
T=12000FH

Reacitve Reliability(RM)	Preventive Maintenance(PM)	Predictive Maintenance(PdM)
$R(t) = e^{-\left(\frac{t}{\eta_1}\right)^{\beta_1}}$	$R(t) = e^{-n\left(\frac{T}{\eta_1}\right)^{\beta_1}} \cdot e^{-\left(\frac{\tau}{\eta_1}\right)^{\beta_1}}$ Where $t=nT+\tau$	$R(t) = e^{-(1-P_1P_2)\left(\frac{t}{\eta_1}\right)^{\beta_1} - \left(\frac{t}{\eta_2}\right)^{\beta_2}} + e^{-\left(\frac{t}{\eta_1}\right)^{\beta_1}} \int_0^t \frac{\beta_2}{\eta_2}\left(\frac{t'}{\eta_2}\right)^{\beta_2 - 1} e^{-\left(\frac{t'}{\eta_2}\right)^{\beta_2} + P_1P_2\left(\frac{t'}{\eta_1}\right)^{\beta_1}} dt'$



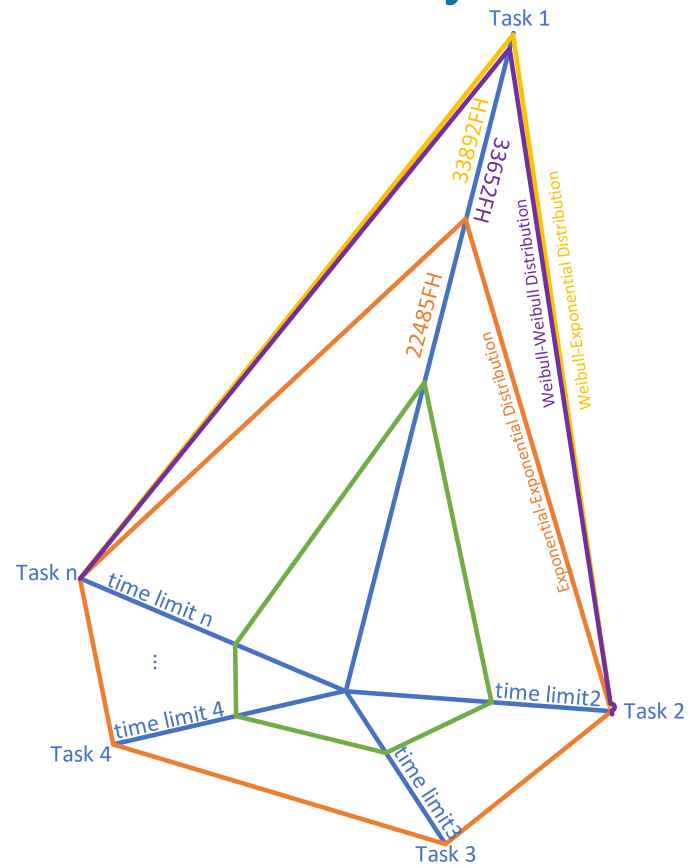


Safety Envelope for MSG-4
--Case Study

With the reliability equation, we can find the safety envelope.

Failure Condition	Reliability Required
Minor	80%
Major	90%
Hazardous	95%
Catastrophic	X

For E-E, W-E, and W-W distributions, the time limits are determined as 22485 FH, 33892 FH and 33652 FH respectively.



Summary

This presentation is NOT:

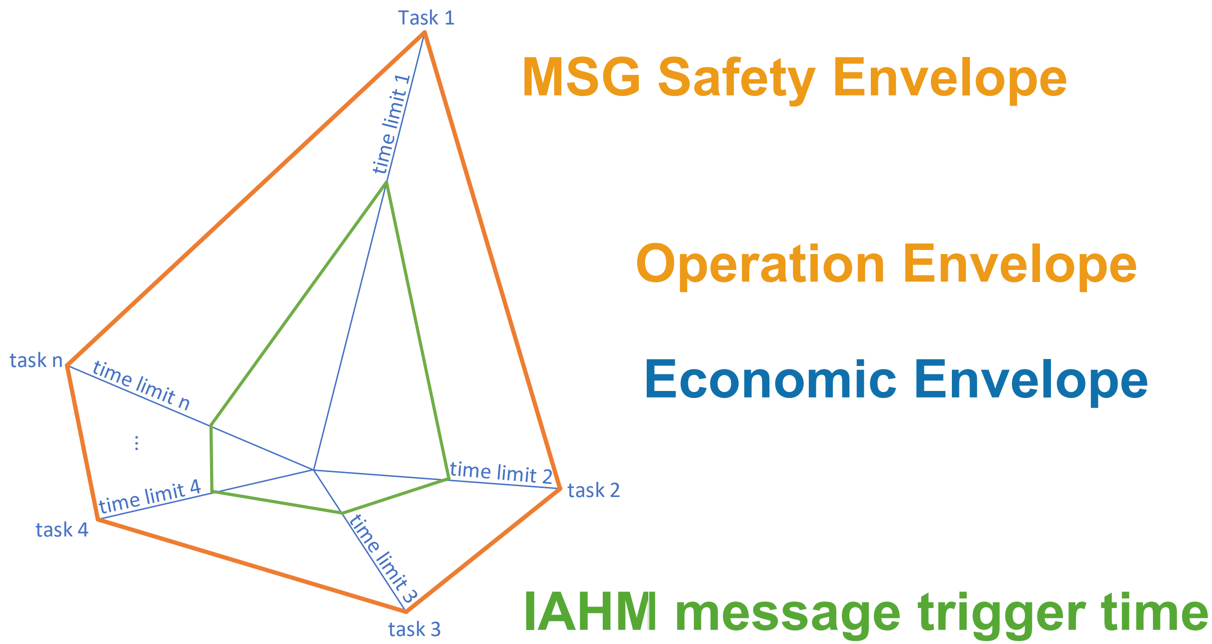
- A task interval computing method
- A specific AHM technique

This presentation IS:

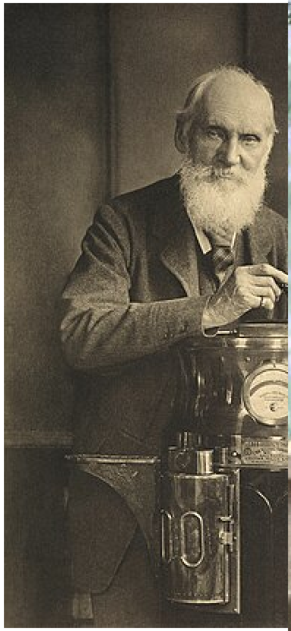
- Clarifying the differences in safety concerns between the certification process and the MRB process
- Proposing new concepts for MSG-4
- Defining the criteria for accepting AHM/AI/Nearly All New Technologies

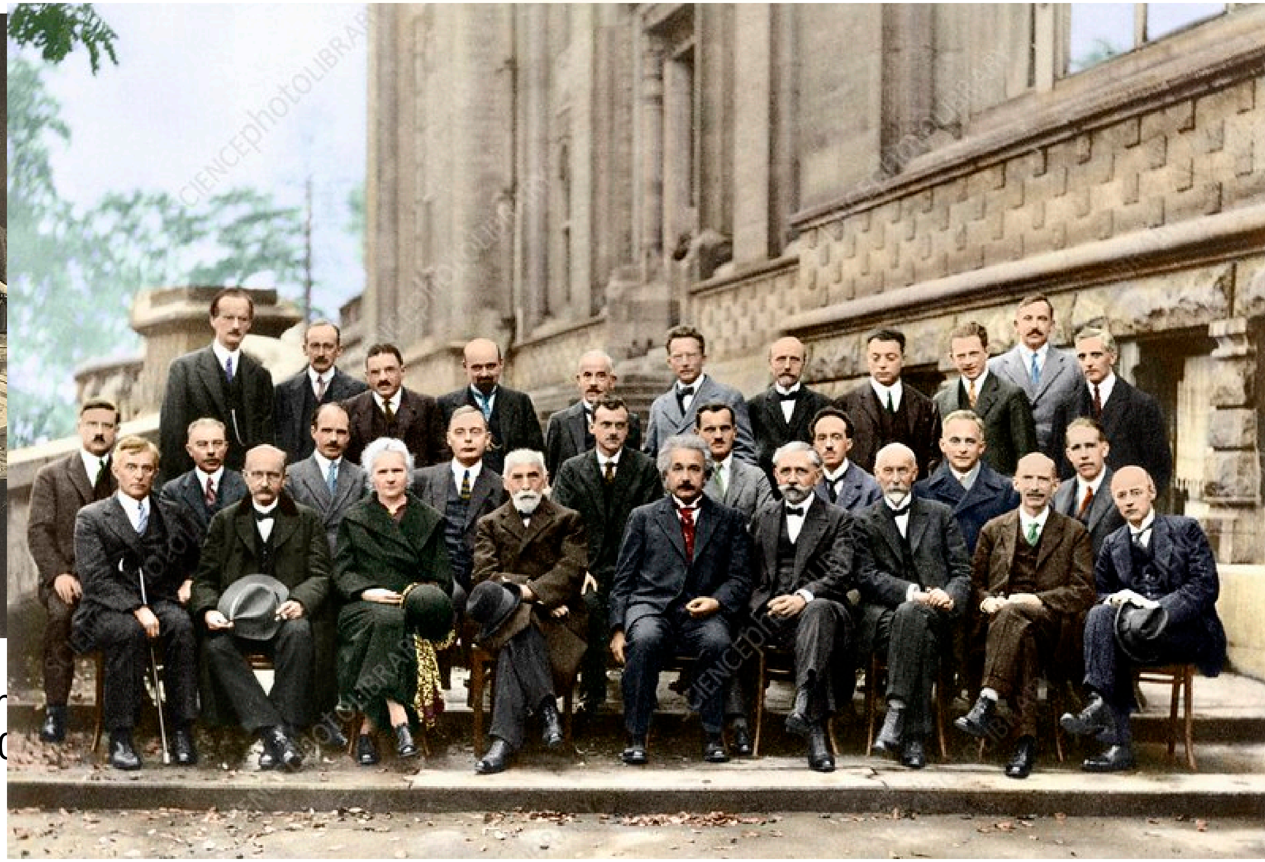
Potential Future Works

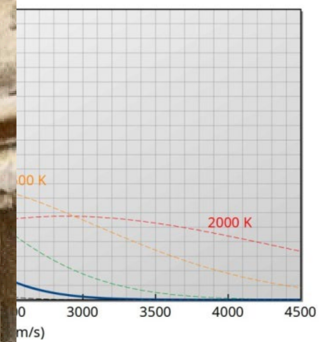
- Clarify the "Archived" status of IP 053;
- Pursue potential improvement for IP 180;
- Improve the Safety/Operational/Economic Envelope Concept.



Two Clouds on the Horizon of 19th Century Physics







Lord Kelvin (Willian
1824-190

n velocity
nction of

Airlines for America™

We Connect the World

Thank You

Any questions, please ping wangyiping@comac.cc