Decompression Sickness

Case Study of Identification of Knowledge and Disposition Gaps Using Principles of Continuous Risk Management

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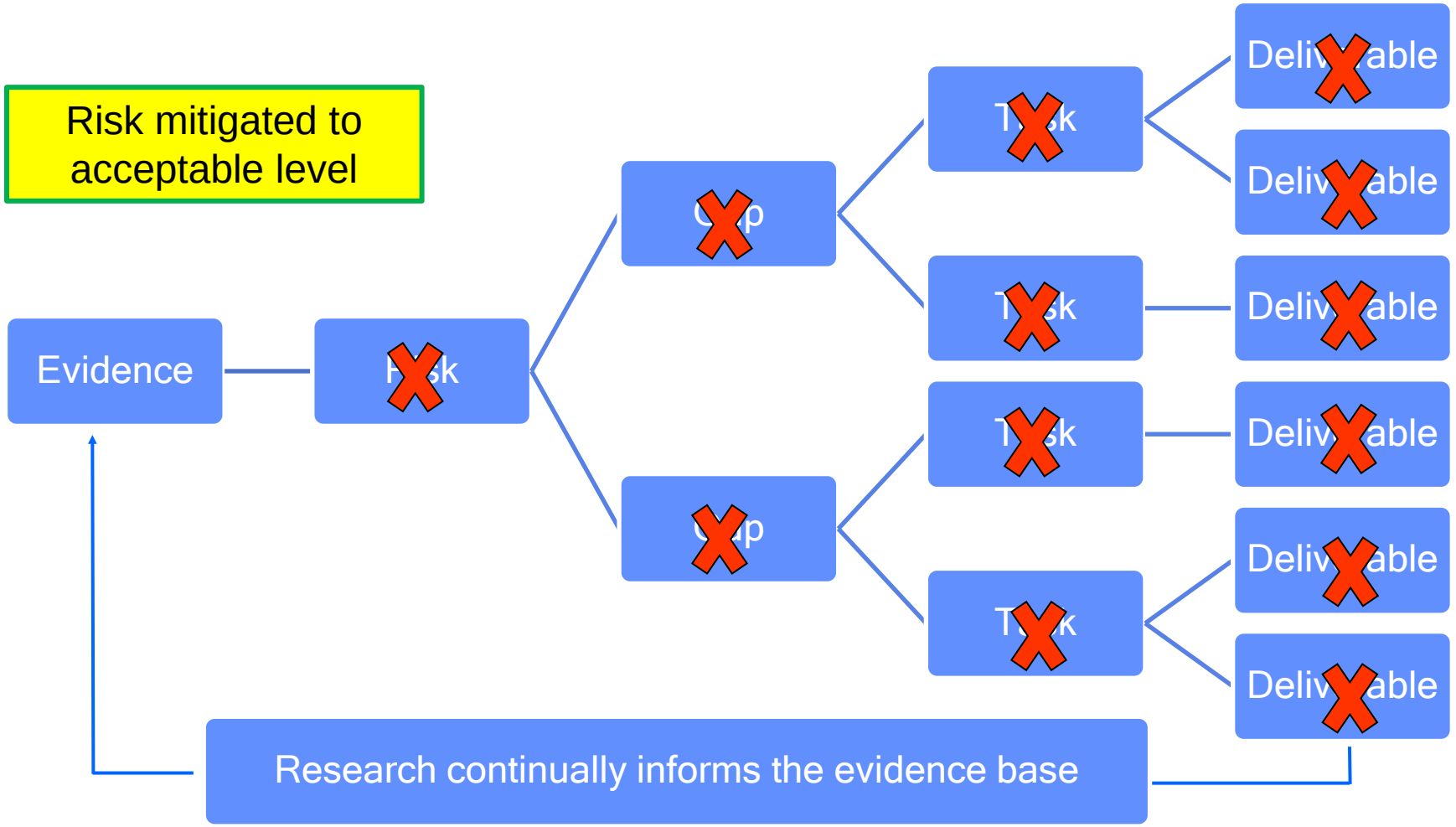
HRP Program Architecture



Translating R&D into Continuous Risk Management

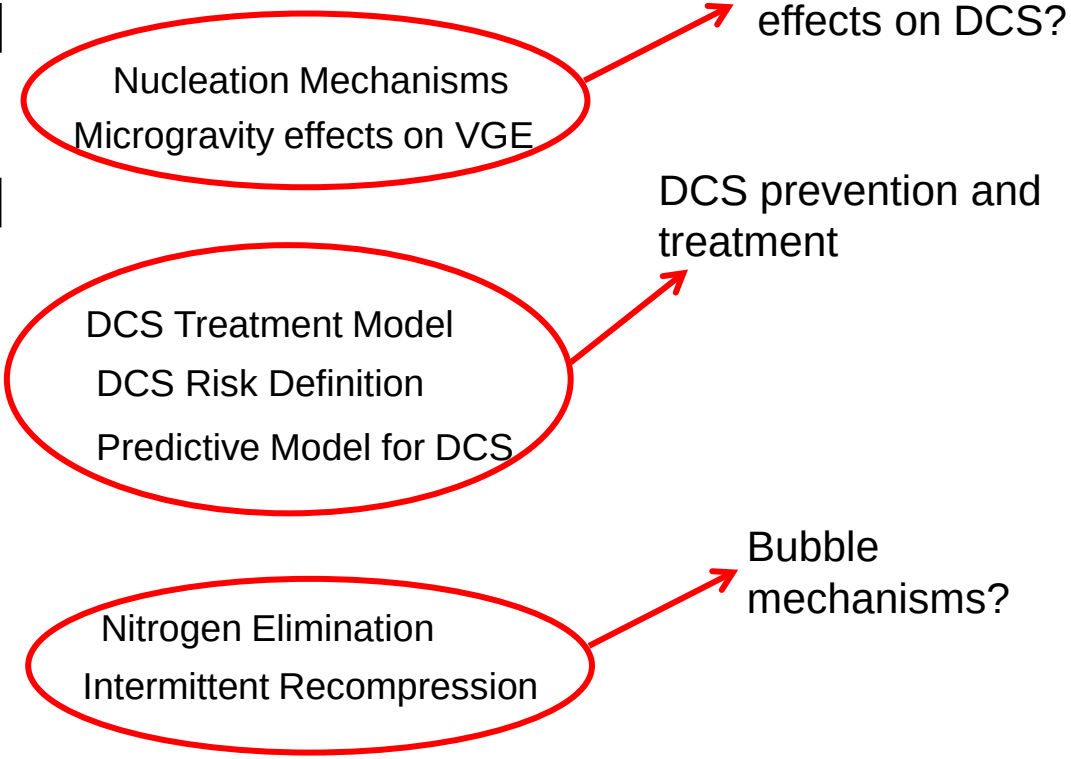
CRM Decision Flow	CRM Activities	R& D Activity	Gap	Target for closure
Risk Definition	Likelihood (L) Consequence (C) Mission Attributes Time frame	Data mining Enabling Technology Phenomenon Mechanism	Knowledge	ID mission attributes Quantify likelihood, uncertainty, consequence
Policy	ID quantitative closure criteria for disposition gaps	Epidemiology, statistics, clinical care guidelines	Disposition-policy	NASA approval of acceptable level risk
Disposition	Watch Accept Mitigate	Techwatch Standards ID & develop countermeasures	Mitigation	Yearly update Flight rule ↓ L or C

Focusing Mitigation Gaps

R&D Activities	Category of Gap	Target for closure	Deliverables
Research on phenomenon or mechanism	Conceptual model	ID risk factors for countermeasure development	Model
Clinical Procedure	Predict	Quantitative modeling	Model
Clinical Procedure	Prevent	Countermeasure to ↓L ± CI	Countermeasure
Clinical Procedure	Diagnose	Measurement protocol	Technology_Tool
Clinical Procedure	Treat	↓ C	Countermeasure
Clinical Procedure	Detect/Monitor	Flight technology	Technology_tool
Clinical Procedure	Rehab	↓ C	Countermeasure
Clinical Procedure	Surveillance	Protocol	Technology_tool

First Draft – Defining the Gaps

- DCS had been a gap under the broad EVA risk
- DCS had no defined gaps, but many tasks
- Initial draft looked for similarity in the tasks
  - Did not consider closure criteria or interim metrics



DCS Gaps – First Draft

Initial

- Too much overlap with several tasks straddling 2, 3 or more gaps
- Knowledge gaps are the most difficult to define closure criteria
- Gaps were not worded with closure in mind

- Mitigation gap held everything else:
  - Risk definition
  - Prediction models
  - Procedures/Flight Rules
  - Treatment

Type	
Knowledge Gap:	Data, phenomenon, mechanism
Knowledge Gap:	Data, phenomenon, mechanism
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Knowledge Gap:	Data, phenomenon, mechanism
Knowledge Gap:	Mechanism
Mitigation gap	

DCS Interim Gaps- Post HRP Review

- Gap creation determined by target for closure

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Gap	Type	Target for Closure
DCS 1: We do not know the acceptable DCS risk with respect to the work efficiency index (WEI) for exploration.	Risk definition & disposition-policy	HSRB approval Approved NASA Standard / Requirement
DCS 2: We do not know the con DCS risk factors to the developm Space Flight Exploration Environ		Obtain effect size as a function of individual variance for each risk factor of interest in order to include in the DCS prediction model
DCS3: We do not know the cond bubble formation, growth and elir tissue		List putative causes to investigate/set of outcomes to be explained
DCS 4: We do not know to what physiological and environmental incorporated and validated in a model DCS for micro and reduced gravity?		Validated model for expected Exploration environment, which meets requirements of NASA-STD-7009
DCS 5: We do not know what validated procedures will adequately prevent DCS?	Mitigation gap- Prevention	PB procedures that meet the accept criteria for DCS prevention, which will be based on the definition of acceptable risk standard for the Exploration environment
DCS6: We do not know what new developments related to DCS will come from other investigators?	Mitigation gap - Watch	Current year/IRP end date x100=% completion

On paper, these gaps sounded different, but when trying to identify how to keep track of interim metrics, we saw that they needed to be reorganized.

Gap 2 and 3 Task Reorganization

Gap 2 - Risk Factors

- Nucleation Mechanisms
- Prevalence of VGE after Depressurization in Microgravity
- Exploration EVA Environment Characterization
- EVA Simulator Development
- Data Mining for DCS Physiological Risk Factors
- N2 Elimination
- Abbreviated Purge
- Exercise Saturation Equivalent Testing

Gap 3 - Bubble Mechanisms

- Intermittent Recompression
- Animal Models to Evaluate DCS
- Exercise Saturation Equivalent Testing
- Nucleation Mechanisms
- N2 Elimination

DCS Gaps – Final
- Both target for closure and interim metrics considered

Gap	Type	Target for Closure
DCS 1: We do not know the acceptable DCS risk with respect to the work efficiency index (WEI) for exploration scenarios.	Risk definition & disposition -policy	HSRB approval Approved NASA Standard / Requirement
DCS 2: We do not know the contribution of specific DCS risk factors to the development of DCS in the Space Flight Exploration Environment.	Knowledge gap: Data, phenomenon, mechanism	Obtain effect size as a function of individual variance for each risk factor of interest in order to include in the DCS prediction model
DCS3: We do not know the mission related factors that contribute to DCS risk	Knowledge gap: Data, phenomenon	EVA Simulator for PB validation trials
DCS 4: We do not know to what extent can physiological and environmental factors be incorporated and validated in a model DCS for micro and reduced gravity?	Mitigation gap-prediction (Model)	Validated model for expected Exploration environment, which meets requirements of NASA-STD-7009
DCS 5: We do not know what validated procedures will adequately prevent DCS?	Mitigation gap-prevention	PB procedures that meet the accept criteria for DCS prevention, which will be based on the definition of acceptable risk standard for the Exploration environment
DCS6: We do not know what new developments related to DCS will come from other investigators?	Mitigation gap - Watch	Current year/IRP end date x100=% completion

Gap 2 and 3 Task Reorganization Final

Start Gap	Task	Final Gap	Rationale
2 , 3	Nucleation Mechanisms	2	Gap 2 focus is physiological and not DRM specific
2 , 3	N2 Elimination	2	
2	Abbreviated Purge	2	
2	Prevalence of VGE after Depressurization in Microgravity	2	
3	Intermittent Recompression	2	
3	Animal Models of Recompression	2	
2	Data Mining for DCS Physiological Risk Factors	-	This is really a subset of work done in many of the tasks and did not need to be called out separately
2	Exploration EVA Environment Characterization	3	Gap 3 focus is on external factors (Environment and EVA factors) and is DRM specific
2	EVA Simulator Development	3	
2 , 3	Exercise Saturation Equivalent Testing	4	Results of this work will actually feed into a separate model / tool to facilitate DCS research

Example Interim Metrics

DCS 1 – Risk Definition (DRM Specific)

Human Research Program

Task	DRM		
	NEA	Lunar	Mars
Define Exploration mission success drivers	0	0	0
Define medical operational drivers and consequences	0	0	0
Analyze trades between levels of risk, prevention and treatment	0	0	0
Develop DCS Disposition Policy for Exploration Program	0	0	0
Define acceptable DCS risk for Exploration Program	0	0	0
HSRB Approval of DCS Risk	0	0	0
Approved DCS Risk Prevention Standard (Deliverable)	0	0	0
Approved DCS Treatment Standard (Deliverable)	0	0	0
Closure metric €= (number of tasks completed/number of tasks) x 100 Note: 0=incomplete, 1=complete			

Example Interim Metrics

DCS 2 – Risk Factor Contributions

#	Task Title	Step #	Step Title	Step Weight	Status: 0=incomplete 1=complete
1	Nucleation Mechanisms	1	Experiment 1	10%	0
		2	Experiment 2	10%	0
		3	Experiment 3	10%	0
		4	Experiment 4	10%	0
2	VGE in Microgravity	1	VGE monitoring capabilities in microgravity while depressurized	10%	0
		2	# subjects complete/# subject needed	10%	0
3	N2 Elimination	1	# subjects complete/# subject needed	10%	0
4	Intermittent Recompression	1	# subjects complete/# subject needed	10%	0
5	Animal Model of Recompression	1	# animals complete/# animals needed	10%	0
8	Abbreviated Purge	1	# subjects complete/# subject needed	10%	0
Closure metric €= Step Weight x Completion Status				**Gap Closure:**	**0%**

Example Interim Metrics

DCS 4 – Models

Credibility Factor	Exercise Saturation Equivalent Model		DCS Prediction Model		DCS Treatment Model	
	Target Score	Actual Score	Target Score	Actual Score	Target Score	Actual Score
Verification	2	1	3	2	2	1
Validation	2	0	3	2	2	1
Input Pedigree	3	2	4	2	3	2
Results Uncertainty	2	1	3	2	2	1
Results Robustness	3	2	3	2	3	2
Use History	3	0	4	2	2	1
M&S Management	2	1	4	1	4	1
People Qualifications	3	1	3	1	4	1

This addresses model development, but what about model maintenance ?

Conclusions

- HRP is an applied research program aimed at mitigating risk.
- The described method provides a unifying framework for identifying gaps and their metrics that can provide meaningful information to continuous risk management.
  - Identification - gaps address each area of CRM decision flow
  - Focus – for closeable gaps
    - ✓ Avoid combination of risk definition and disposition in same gap
    - ✓ Use of standard concept of clinical care to focus mitigation gaps
- Consolidation of knowledge gaps on the mechanism of DCS helped us achieve well defined closure criteria and interim metrics
- Current orientation of HRP - destination agnostic
  - Use of interim metric for each exploration DRM