National Aeronautics and Space Administration

IMPACT, A TOOL SUITE FOR CREW HEALTH AND PERFORMANCE SYSTEM TRADE ANALYSES AND DECISION SUPPORT- STATUS OF DEVELOPMENT

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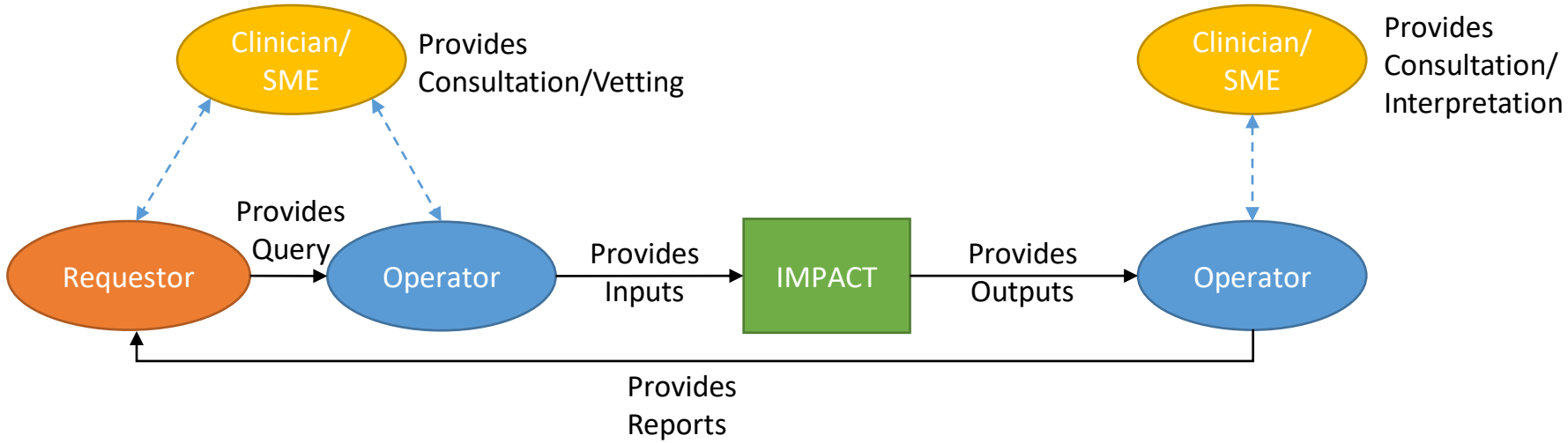
Informing Mission Planning via Analysis of Complex Tradespaces

Purpose of IMPACT

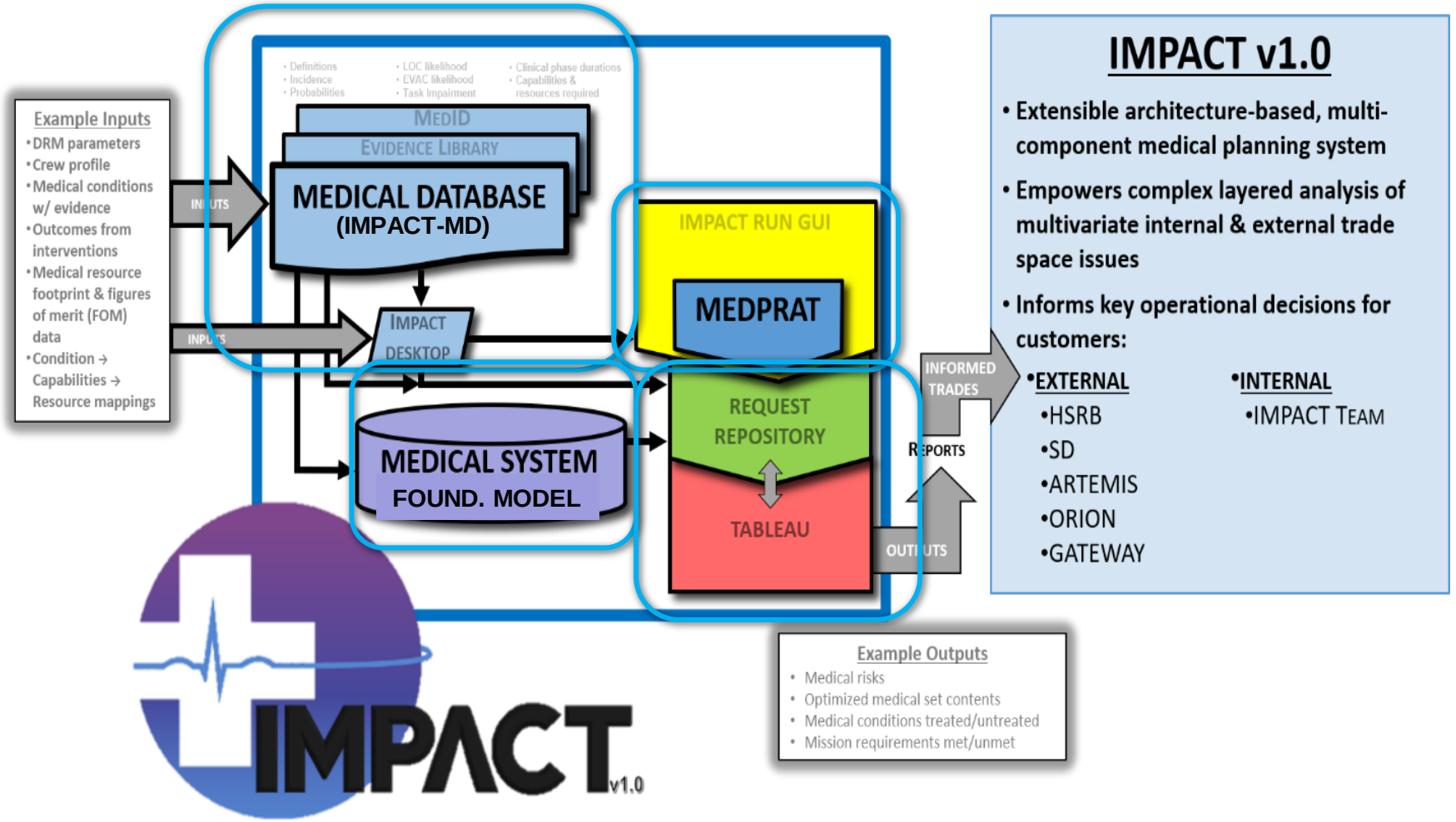
Need to:

- Provide a data-driven means to inform human health and performance risk mitigation
- During resource-constrained exploration mission development
- Enabling systematic trade studies to evaluate options



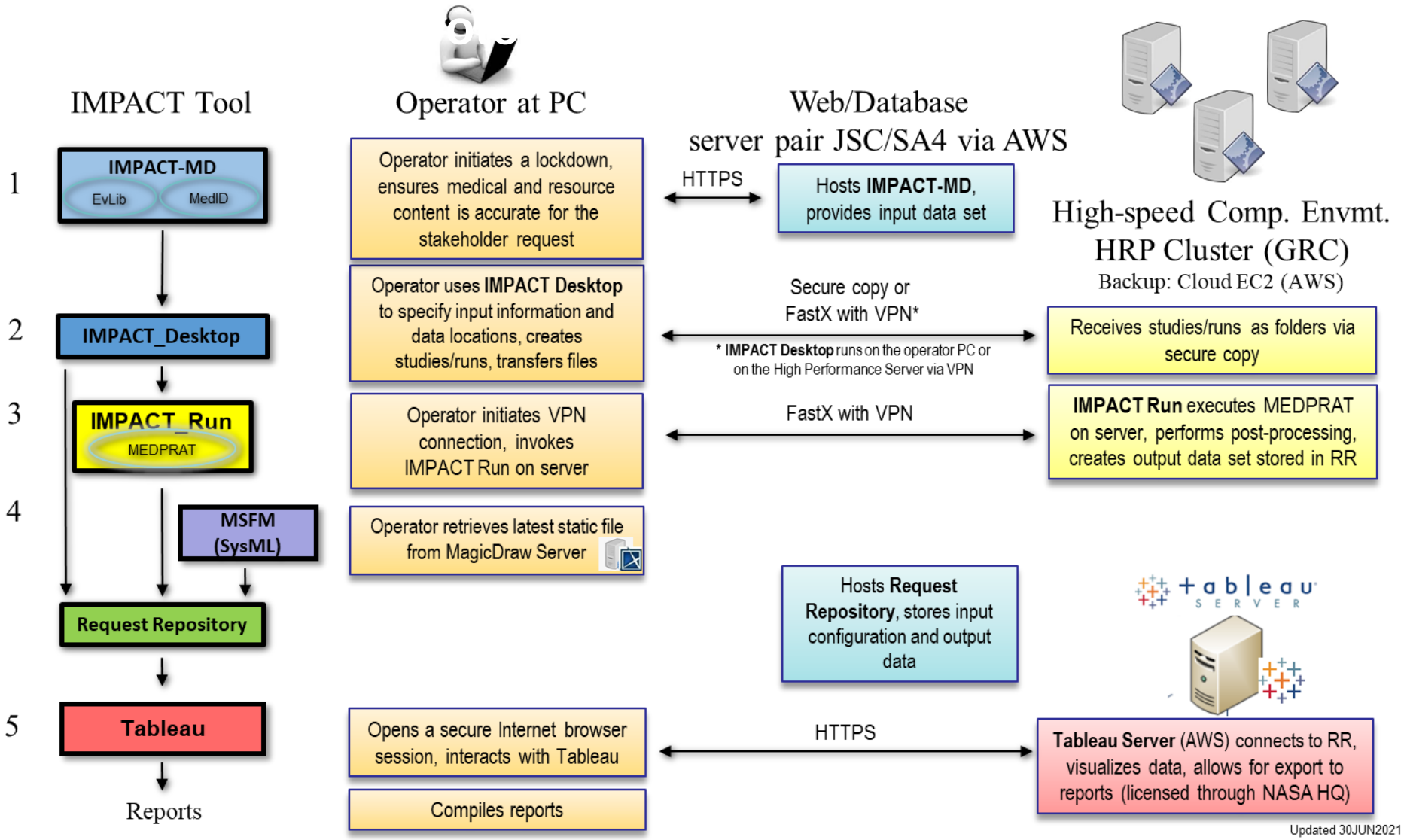
SME = Subject Matter Expert

IMPACT is a suite of tools working together

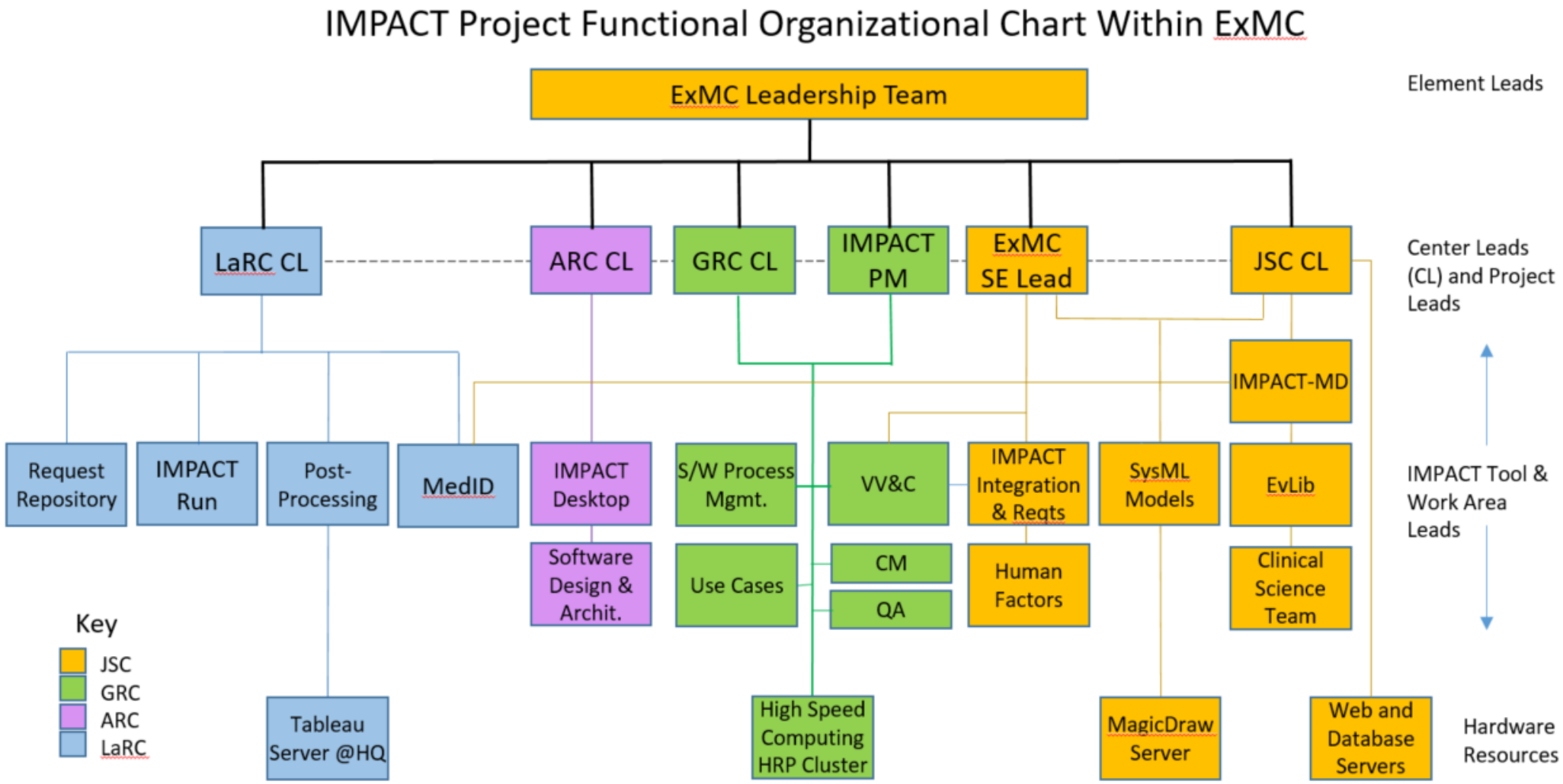


MEDPRAT = Medical Extensible Dynamic Probabilistic Risk Assessment Tool

Physical configuration diagram for IMPACT v1.0



IMPACT is a highly collaborative project among four NASA Centers

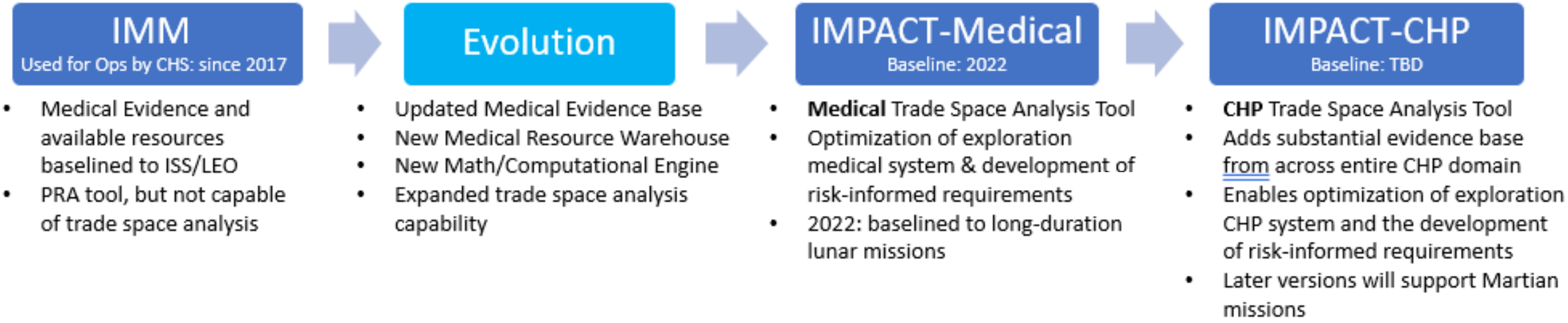


IMPACT: Part of the Evolution of Probabilistic Risk Analysis (PRA) for Crew Health and Performance

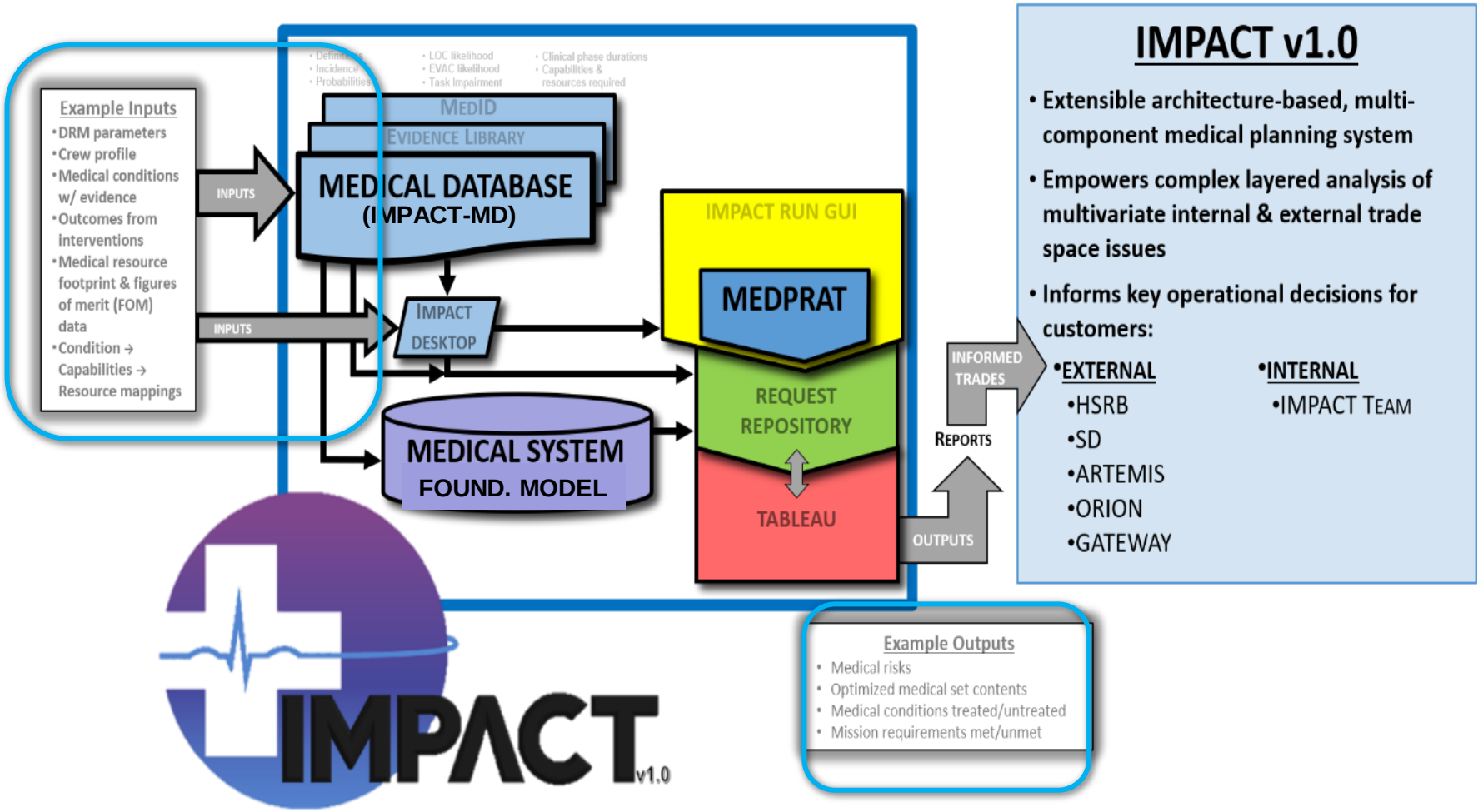
- **HRP/ExMC is developing IMPACT to assist HEO and OCHMO/HMTA in understanding the impacts of mission design and vehicle resource allocation on medical risk and ultimately Crew Health and Performance (CHP)**

- **IMPACT supports data-driven and evidence-based decision-making throughout the entire mission life cycle**

- **IMPACT quantifies the effects of specific design decisions on medical and CHP risks and allows for analysis of complex tradespaces**

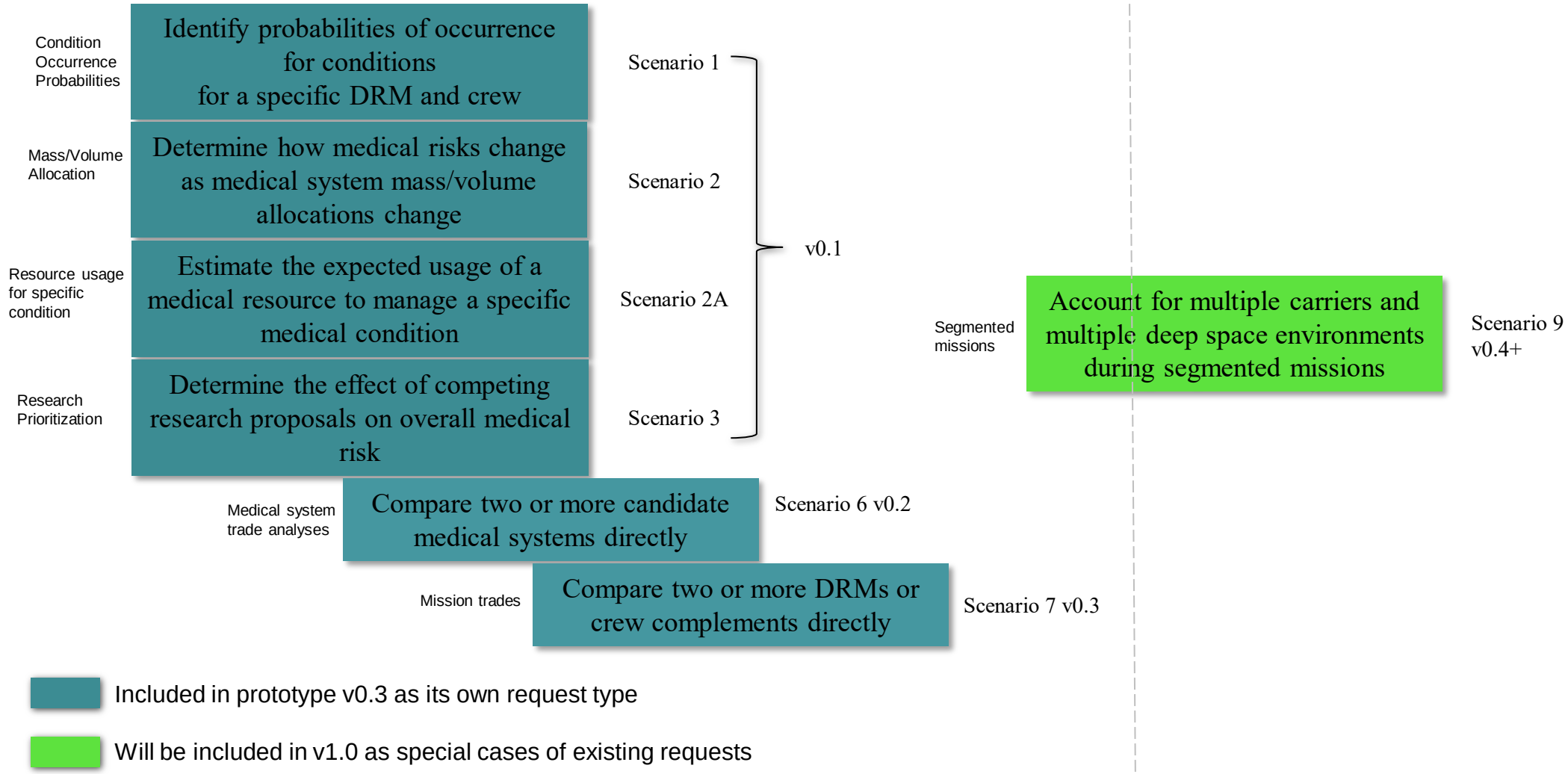


IMPACT is a suite of tools working together



Use Cases for IMPACT 1.0 – Progress to date on implementing the Conops scenarios

- **Implementation of use cases from the IMPACT ConOps progressing to v1.0**



Condition Occurrence Probabilities (Sc. 1)

AGILE USER STORY

- **As a: Member of MedOps**
- **I want to: Determine the occurrence probabilities of medical conditions for a specific DRM and crew complement**
- **So that I can: Initiate the AMCL process for that mission, and define the level of care and capabilities needed**

- Data displayed as “super tables” with much flexibility in filtering by conditions, sorting by column, ranking, exporting to reports
- Probabilities of best/worst case progression of conditions are also calculated

Condition Occurrence Probability

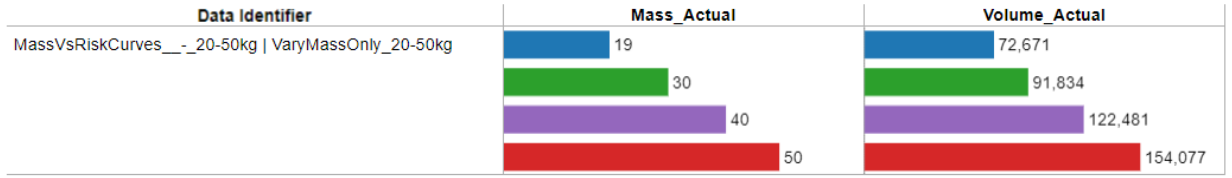
Condition Name	Probability of Condition Occurrence			
	One Or More	One Or More BestCase	One Or More WorstCase	Zero
SLEEP DISORDER	1.0000	0.9893	0.0106	0.0000
SKIN ABRASION	1.0000	0.9234	0.0766	0.0000
SKIN RASH	1.0000	0.9710	0.0289	0.0000
EYE IRRITATION/ABRASION	0.9999	0.9952	0.0047	0.0001
HEADACHE (LATE)	0.9984	0.9916	0.0067	0.0016
BACK SPRAIN/STRAIN	0.9958	0.9717	0.0241	0.0042
SPACE MOTION SICKNESS (SPACE ADAPTATION)	0.9932	0.8714	0.1218	0.0068
NASAL CONGESTION (SPACE ADAPTATION)	0.9650	0.9618	0.0032	0.0350
BACK PAIN (SPACE ADAPTATION)	0.9313	0.9039	0.0273	0.0687
INSOMNIA (SPACE ADAPTATION)	0.9223	0.8849	0.0374	0.0777

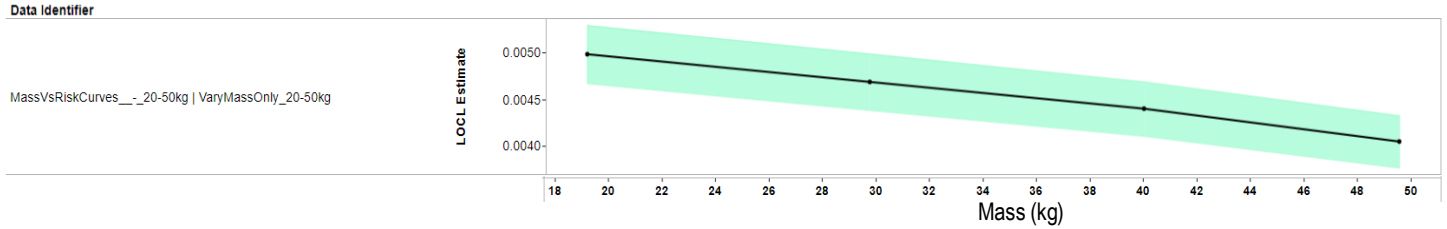
Mass/Volume Allocation (Sc. 2)

AGILE USER STORY

- **As a: Medical systems engineer**
- **I want to: Plot LOCL, QTL/TTL, and RTDC associated with the optimized medical systems selected under varying constraints for mass and/or volume**
- **So that I can: Understand how medical risk changes with changes to the mass and/or volume allocation for the medical system**

- Data displayed as plots of risk factor(s) vs. cost factor(s) with a quantitative X-axis and uncertainty bands displayed





- Medical set contents for each point on the curve, sortable by resource name, quantity, mass or volume

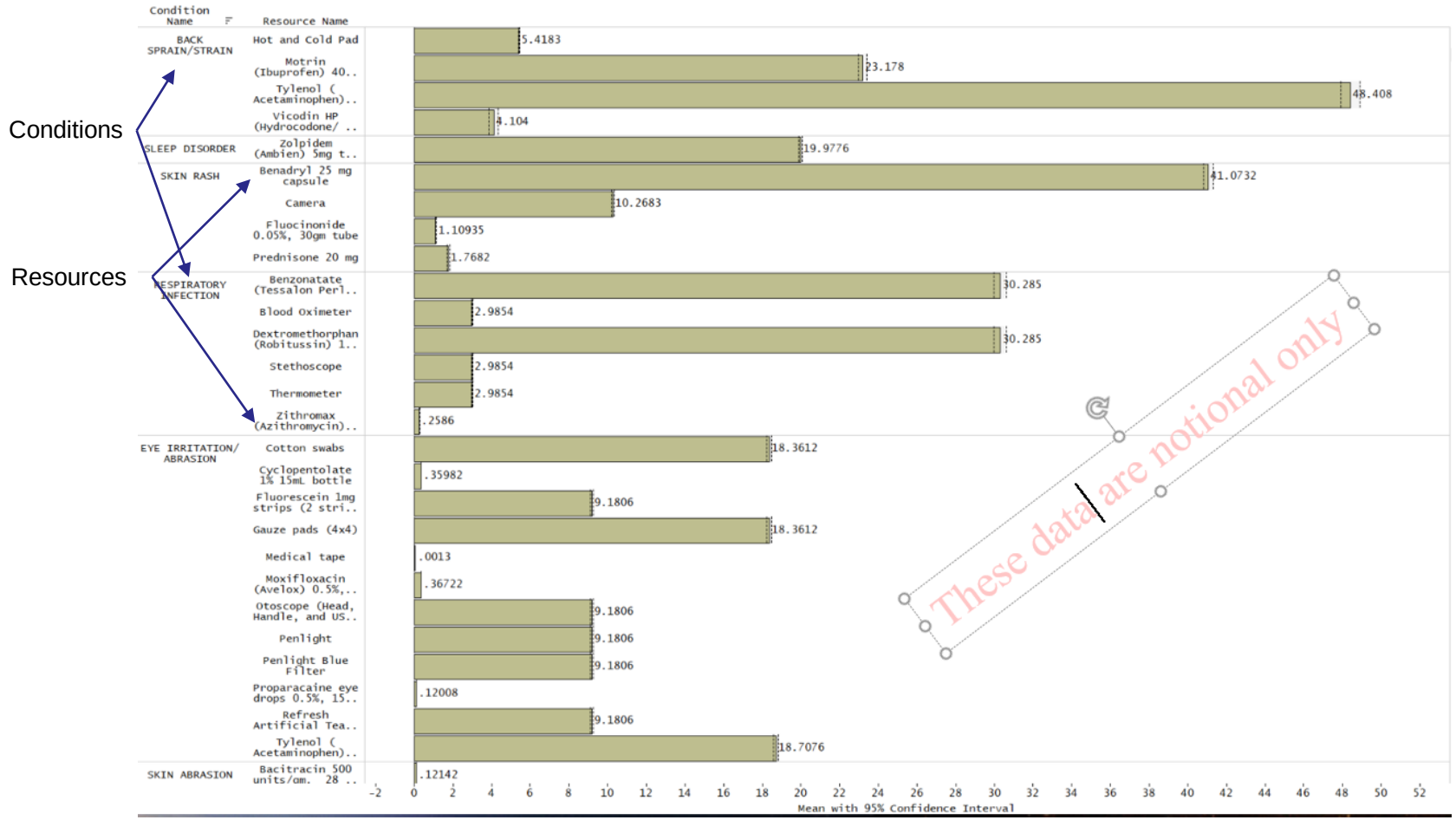
ResourceName	Data Identifier	Total Resource Quantity	Total Resource Mass (kg)
ECG Monitor (Device, USB Charge Cable, Lead Set Cable, Cue Card)	VaryMassOnly_20-50kg | 50kg	1	1.470e1
	VaryMassOnly_20-50kg | 40kg	1	1.470e1
	VaryMassOnly_20-50kg | 30kg	0 removed	0.000e0
	VaryMassOnly_20-50kg | 20kg	0	0.000e0
VOS Intubated Patient Hardware (Ventilator/Respirator)	VaryMassOnly_20-50kg | 50kg	1	5.000e0
	VaryMassOnly_20-50kg | 40kg	1	5.000e0
	VaryMassOnly_20-50kg | 30kg	1	5.000e0
	VaryMassOnly_20-50kg | 20kg	0 removed	0.000e0

Resource Usage by Condition (Sc. 2A)

AGILE USER STORY

- **As a: Member of CHS**
- **I want to: Determine the expected amount of each resource needed for managing a specific medical condition**
- **So that I can: Understand how the inclusion/exclusion of a specific medical condition on the AMCL for a mission will affect the contents of the optimized medical set and its total mass/volume**

- Data displayed as bar charts of individual resource usage within a particular medical condition

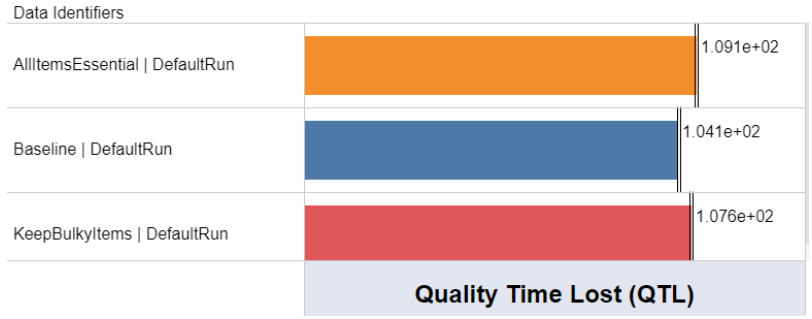


Medical system comparison and trade analysis (Sc. 6)

AGILE USER STORY

- **As an: Exploration program or CHP system manager**
- **I want to: Trade on and compare candidate medical system options directly**
- **So that I can: Understand how to fully optimize the choice of medical system to mitigate medical risk while meeting the mission constraints**

- Data displayed as bar charts of individual cases with modifications to the baseline medical set, including forced inclusion/exclusion of items, different clustering approaches, differing initial quantities, etc.



- Visualizations exist to analyze exhaustion frequency of any resource associated with a medical condition

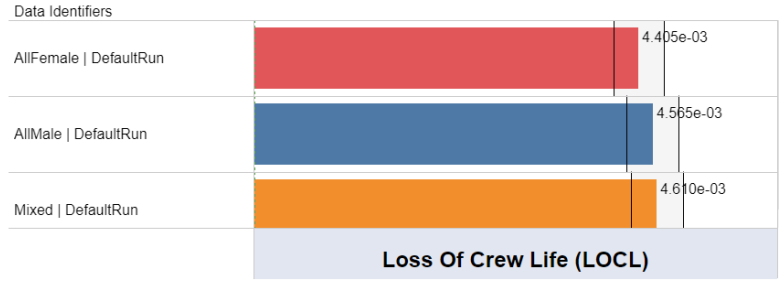
Medical Condition	ResourceName	Data Identifier	Resource Exhaustion Frequency	Resource Quantity
Chest Injury	Ultrasound gel (2 packets)	AllItemsEssential | DefaultRun	0%	5.00
		Baseline | DefaultRun	0%	10.00
		KeepBulkyItems | DefaultRun	1%	4.00
	CMRS	AllItemsEssential | DefaultRun	0%	1.00
		Baseline | DefaultRun	0%	0.00
		KeepBulkyItems | DefaultRun	0%	1.00
	ECG Monitor (Device, USB Charge Cable, Lead Set Cable, Cue Card)	AllItemsEssential | DefaultRun	0%	1.00
		Baseline | DefaultRun	0%	0.00
		KeepBulkyItems | DefaultRun	0%	1.00
	Ultrasound machine	AllItemsEssential | DefaultRun	0%	0.00
		Baseline | DefaultRun	0%	1.00
		KeepBulkyItems | DefaultRun	0%	1.00

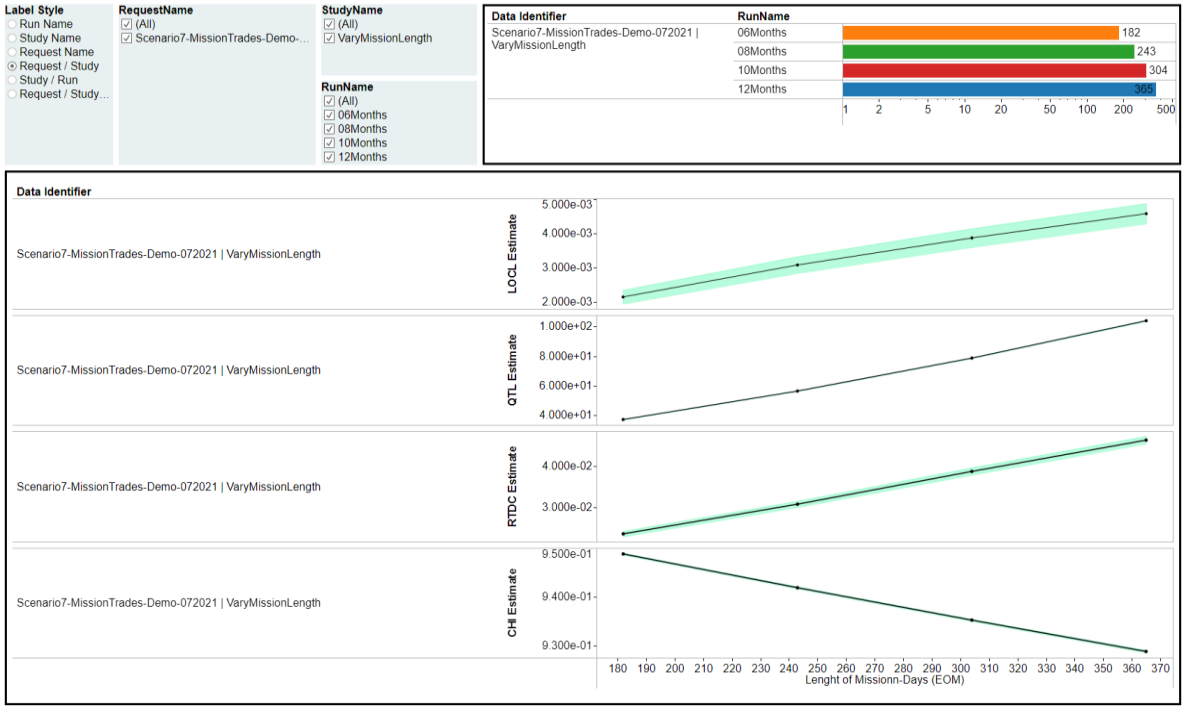
Mission/crew trades (Sc. 7)

AGILE USER STORY

- **As a: Mission manager**
- **I want to: Use IMPACT to predict how changing the DRM in any fashion (duration, EVAs, etc.) and/or changing the attributes of the crew affects overall medical risk**
- **So that I can: Make decisions regarding DRM changes and crew selection while considering medical risk among a number of other factors**

- Data displayed as bar charts for categorical X-axis trades (e.g., different crew attributes, different activities, etc.), and as charts for quantitative X-axis trades (e.g., mission duration, number of EVAs)

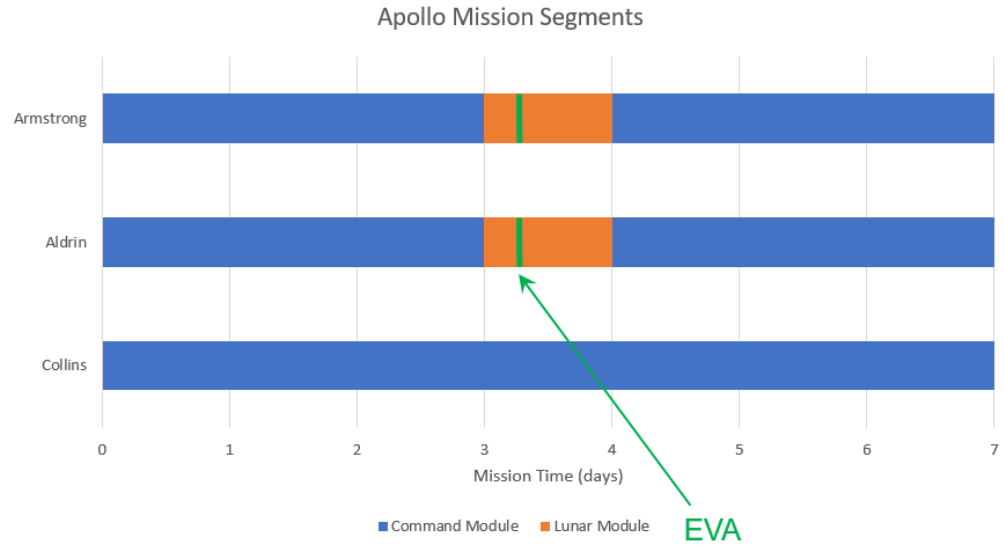




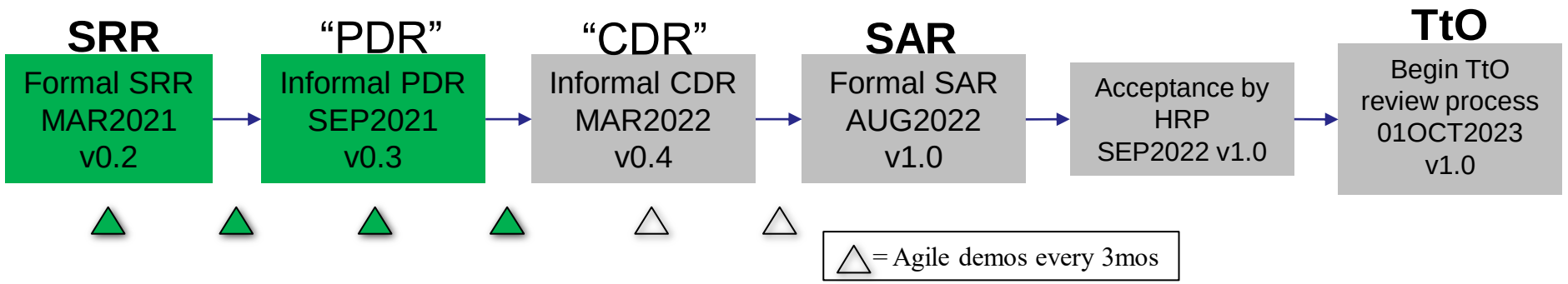
IMPACT: Part of the Evolution of PRA for Crew Health and Performance

- **IMPACT enhances PRA with new capabilities to meet the unique challenges of <u>Exploration missions</u>**
  - Updated and expanded evidence base
    - Consideration of Exploration and deep space environments
    - Updated terrestrial evidence since iMED release
    - Expanded medical condition list (120+)
    - Improved modeling of impairment relative to performing mission tasks
    - Accounts for different types of EVA and limited opportunities for RTDC
    - **Segmented missions, multiple carriers and habitats allow for more realism in simulations**

Segments are defined time periods within the mission timeline, mapped to one or more individual crew members, during which events can occur in an IMPACT simulation



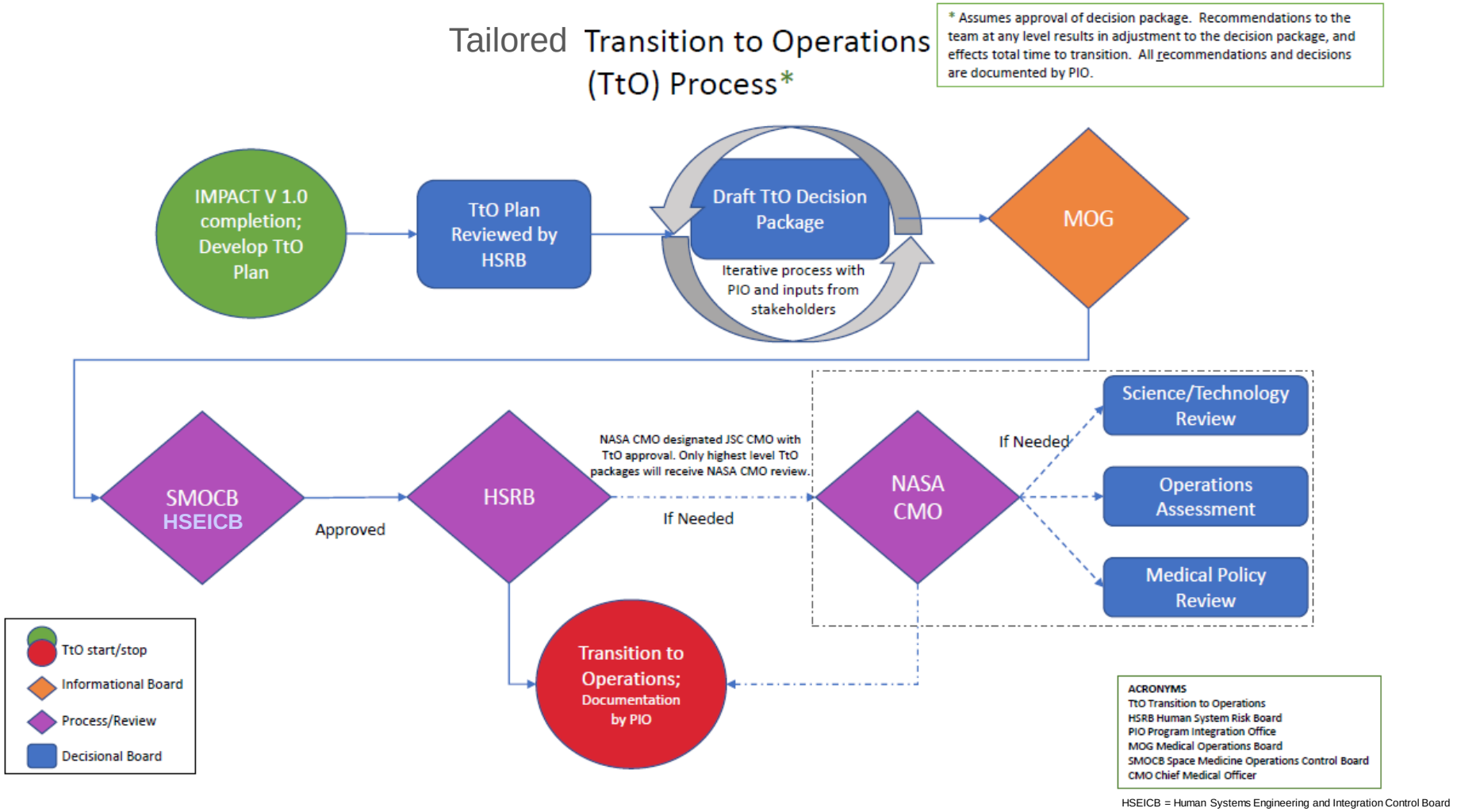
IMPACT Tailored Review Process from NPR 7123.1



- **Formal SRR and SAR, informal PDR and CDR**
  - Design/development phase uses a modified Agile strategy with frequent customer demos to evaluate the design
  - "Informal" reviews to demonstrate project maturity level commensurate with the traditional SE milestones from 7123.1
  - The standing panel participates in the formal reviews and (optionally) in the informal reviews

IMPACT SRR/SAR Panel Members	
Chair: Sandeep Shetye **HRP IT**	Michael Anderson (formerly Michael Conover) **Safety TA**
Neal Zapp **OCHMO/HMTA**	Dan Buckland **HSRB**
Binaifer (Bini) Kadwa **CHS**	Chris Haas **SD (MedOps)/Flight surgeon**
Theresa (Terri) Bradshaw **SF/SE&I**	Deepak Kulkarni **HRP IT**
Brian O'Hagan **Engineering TA**	

IMPACT Tailored TtO Approval Process from NPR 8900.1B



- The IMPACT TtO Plan (PLN-0037) defines how the TtO proposal package will be compiled, submitted, reviewed and approved to transition IMPACT v1.0 to CHS for operational use

Questions?

Thank you for listening!

Backup:
Using IMPACT to create an Optimized Medical Set

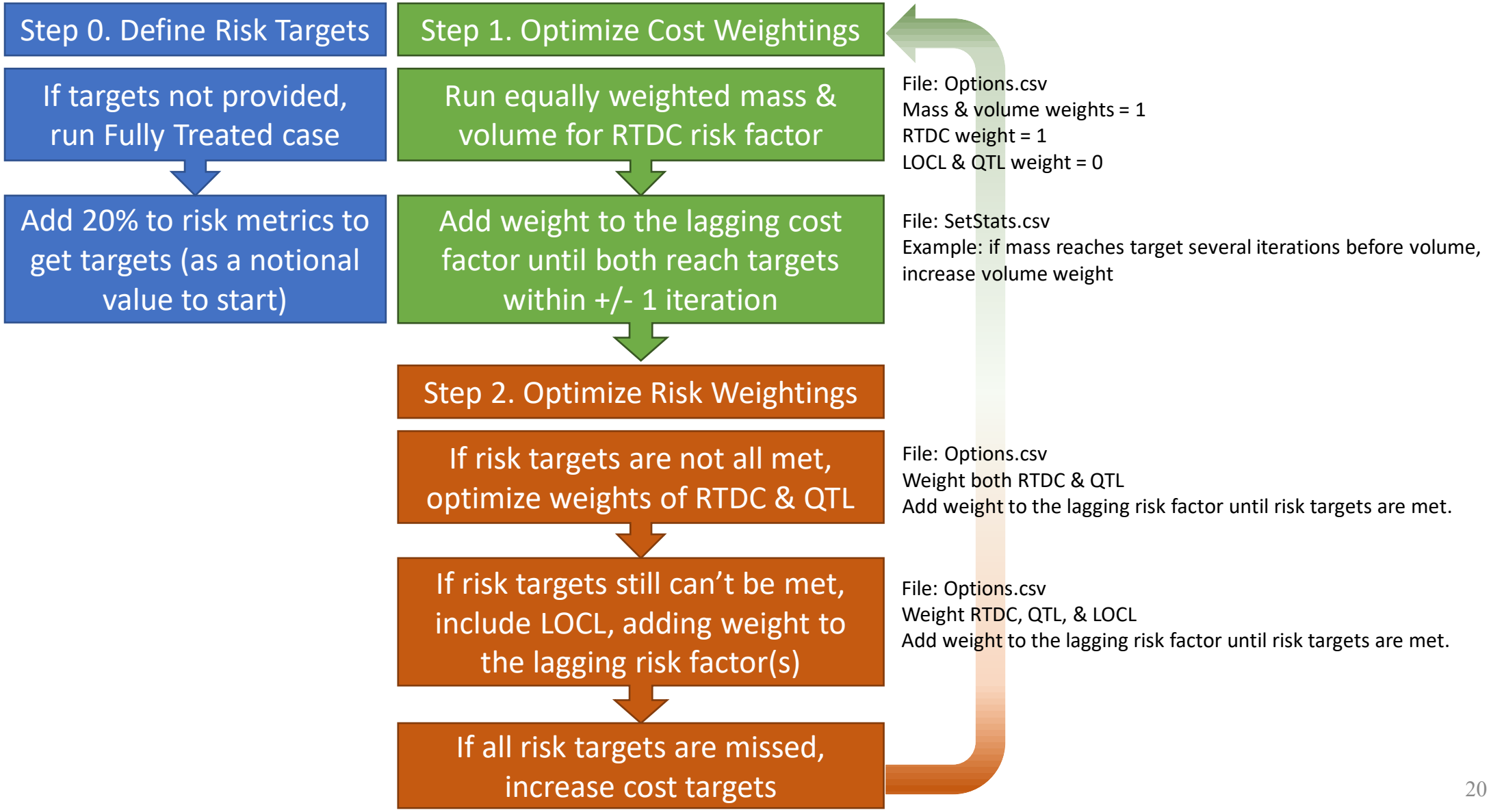
Work was completed last year

- **Thanks to our interns Sarit Dhar and Kendall Farnham**

Details

- **Our Tableau visualizations have improved since then but the underlying principles are still valid**
- **Our new MD Condition List and statistical information is being updated at the end of January and this analysis still uses the old lockdown 68 condition from IMED**

Multi-factorial Optimization Flow Chart



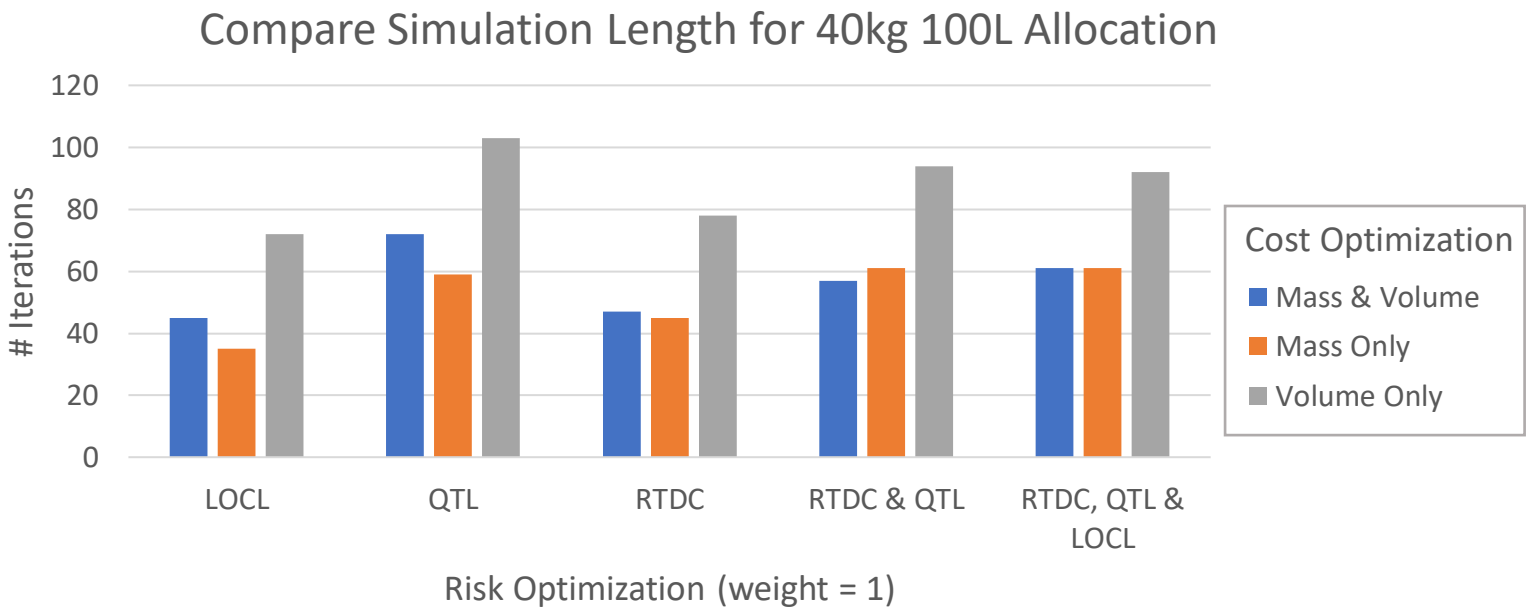
Parameters and Targets

- Mission details:
  - 1 year duration
  - 8 planned EVAs
  - 1 initial SAS condition
- Crew: 2M, 2F
  - Crowns
  - Abdominal Surgery
  - Contacts
- Set selector: 100k trials
- Simulator: 200k trials

- Cost
  - Targets: Mass/Volume allocation (Variable)
  - Weightings: (Variable)
- Risk
  - Targets:
    - LOCL: 0.005
    - QTL: 122 days
    - CHI: 91.6%
    - RTDC: 0.052
  - Weightings: (Variable)

Multi-factorial Optimization

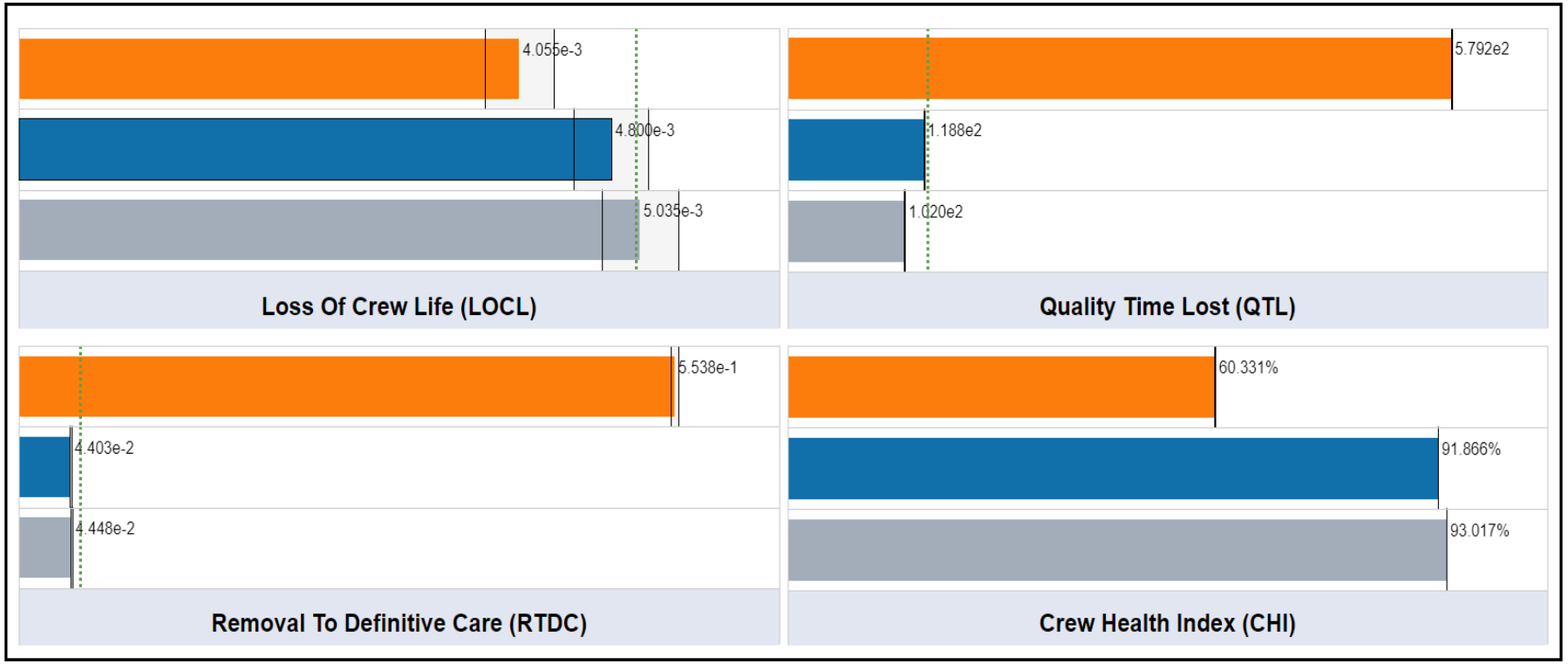
- Purpose: Determine most efficient optimization strategy
- Method: Run single cost and risk factor optimization on 40 kg, 100 L
- Results: Optimizing for mass (or equally weighted cost) is a reasonable starting point
  - Optimizing for volume only is the least efficient starting point



Single Risk Factor Optimization

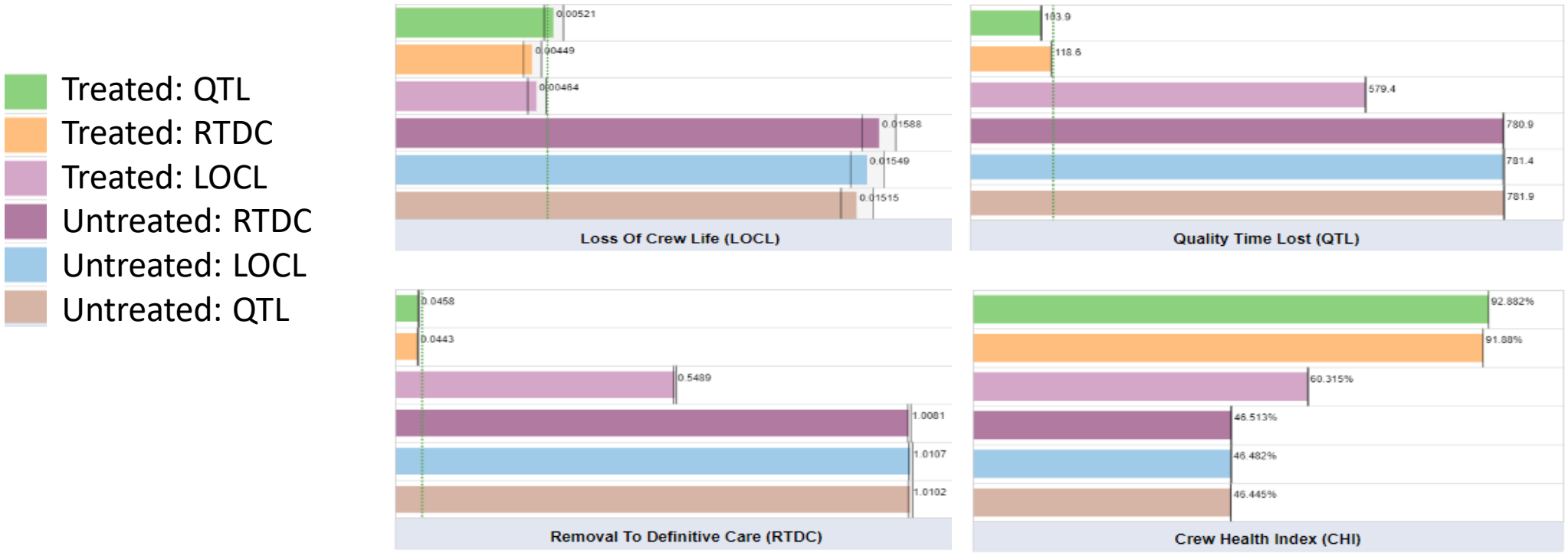
- Purpose: Determine most reliable risk factor for optimizing cost targets
- Method: Run single risk factor optimization on 50 kg, 125 L
- Results: RTDC is best indicator

- LOCL = 1
- RTDC = 1
- QTL = 1



Single Risk Factor Optimization

- Purpose: Determine most reliable risk factor for optimizing cost targets
- Method: Run single risk factor optimization for treated and untreated case (40 kg, 100 L)
- Results: RTDC is best indicator, treated case correctly results in lower risk



Stats on 10 runs vs. single risk factor

- Purpose:
  - characterize uncertainty in outcomes among identical simulations
- Method: Run 10 trials for single risk factors
  - Large mass/vol allocation (60 kg, 150 L) with 1:1 weighting
  - Optimize ratio for single risk factors
- Result: RTDC is best indicator
  - Met targets, lowest SD, SEM, and variance
  - Why? Medical significance

Optimized for RTDC only

60kg 150L	Weighted Risk:	LOCL	QTL	RTDC
Risk target				
LOCL (0.005)	Avg	0.0039	0.0043	→ 0.0042
	SD	0.0001	0.0002	0.0001
	Var	0.0000	0.0000	→ 0.0000
	SEM	0.0000	0.0001	0.0001
QTL (122.5)	Avg	576.4104	102.3205	→ 116.2802
	SD	0.2201	1.0604	0.1683
	Var	0.0484	1.1245	→ 0.0283
	SEM	0.0778	0.3749	0.0753
RTDC (0.052)	Avg	0.5451	0.0441	→ 0.0435
	SD	0.0013	0.0011	0.0008
	Var	0.0000	0.0000	→ 0.0000
	SEM	0.0005	0.0004	0.0004

→ All targets met

→ Lowest variance

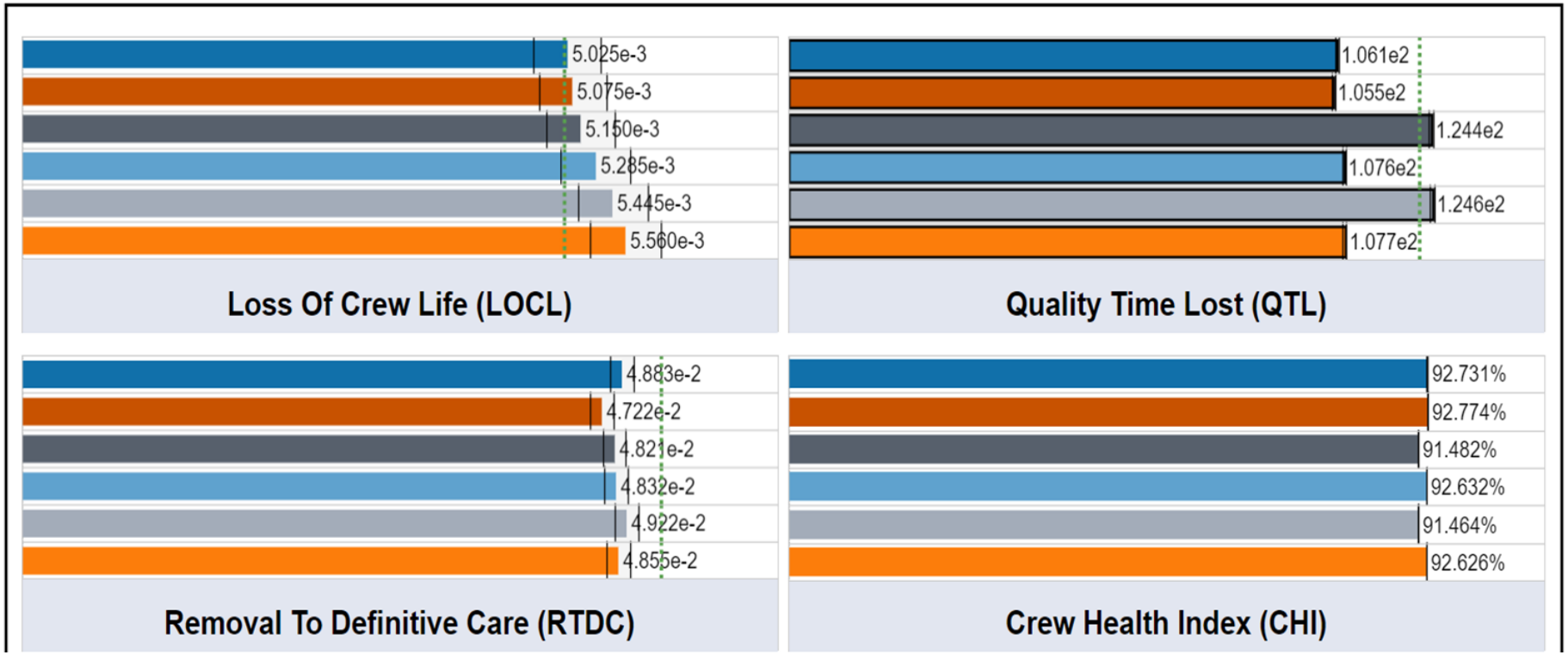
Risk vs Mass/Volume

- Purpose: Determine how risk changes when we vary mass and volume
- Method: Run mass and volume allocations 30kg/75L up to 100kg/250L
- Result: Risk targets are more difficult to meet for tighter mass/volume allocations

Risk vs Mass/Volume (30 kg, 75 L)

Weightings (Key)

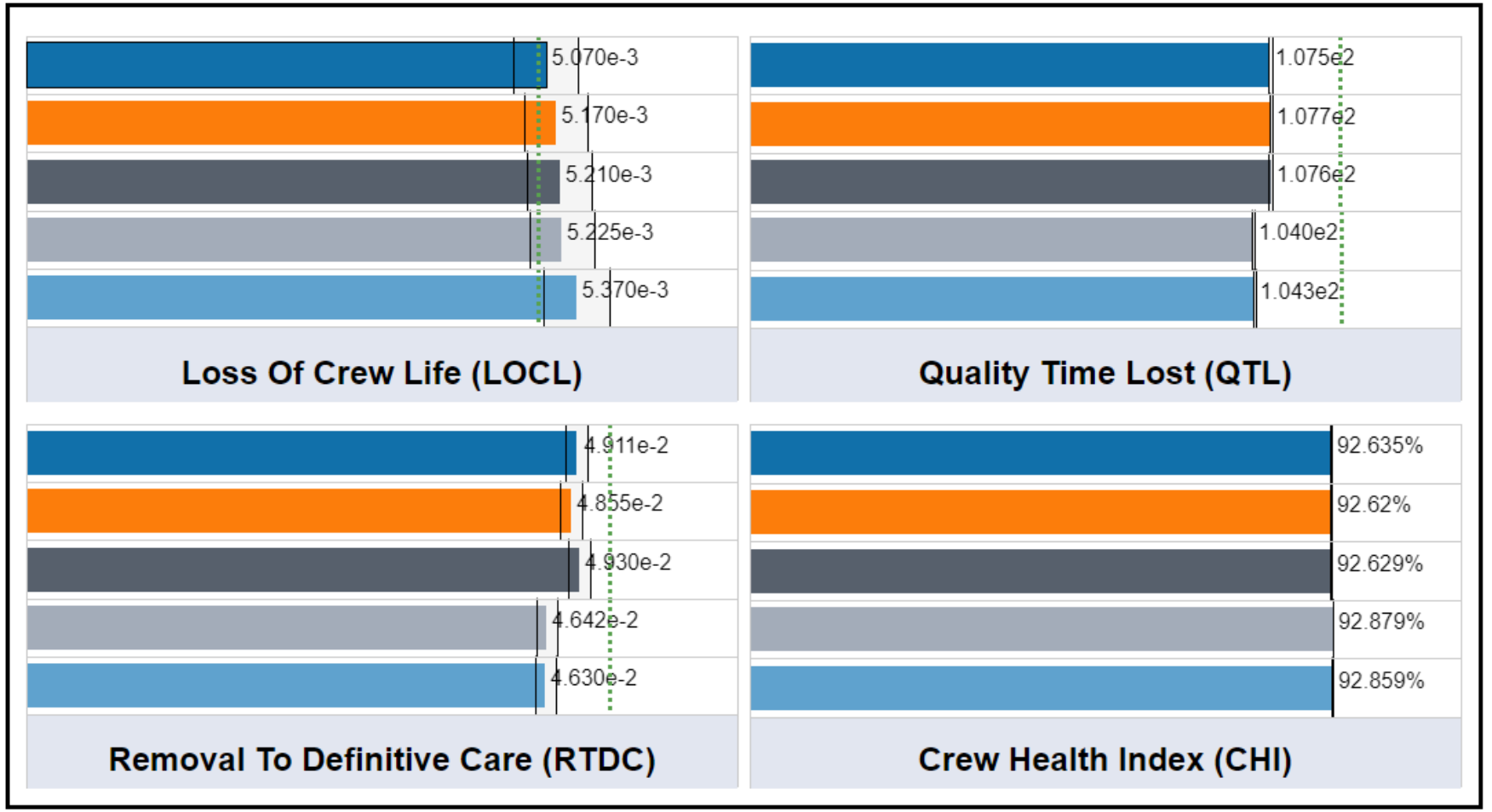
LOCL	QTL	RTDC
1	1	1
1	2	2
1	0	1
0	1	1
0	0	1
1	4	4



Risk vs Mass/Volume (35 kg, 87.5 L)

Weightings (Key)

LOCL	QTL	RTDC
1	1	1
2	1	1
3	1	1
1	4	4
0	0	1



Conclusion

- We have a robust path and steps we can for use to use the MEDPRAT set selector for diminishing risk for a variety of missions.

- **End of IMPACT Overview**
- **Questions?**