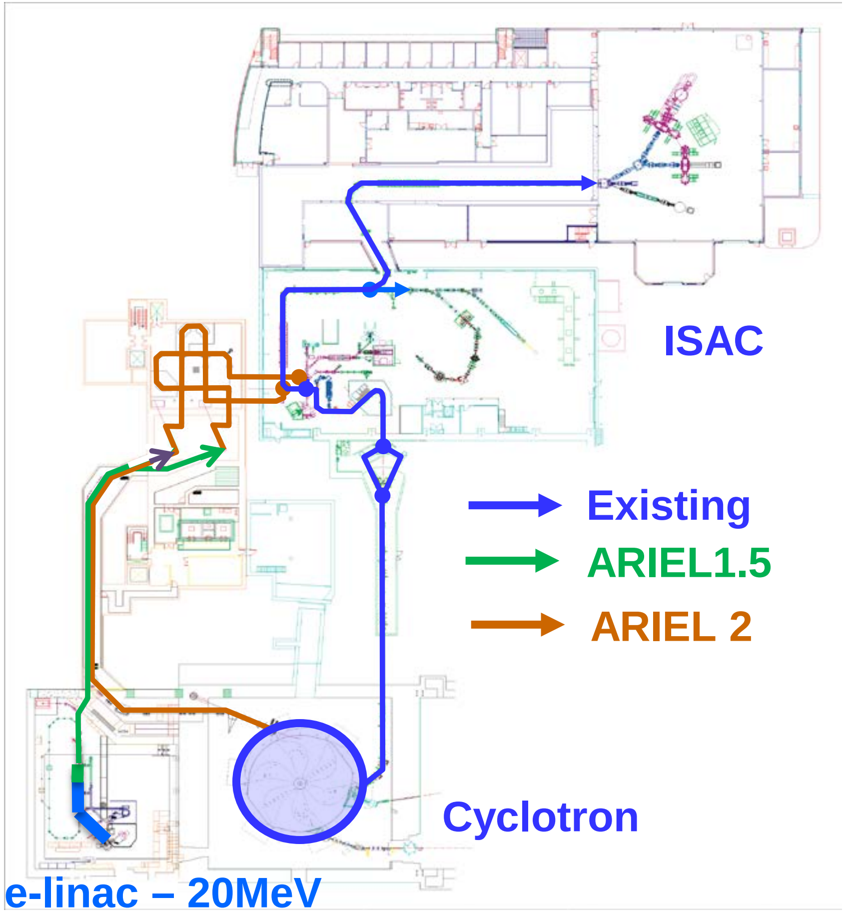
TRIUMF

Canada’s national laboratory
for particle and nuclear physics
and accelerator-based science

Operational model and operations ramp-up for ARIEL

Bob Laxdal

ARIEL Town Hall, Jan. 11, 2017



Completing & operating ARIEL is central to realizing the laboratory vision:

•ARIEL will **triple** our RIB output as we bring on-line a second (AETE) and third (APTW) target area to complement the existing ISAC (ITW/ITE) target area

•The scheduling and beam delivery of three RIBs simultaneously will challenge operations and technical support

•An operation model for ARIEL/ ISAC/ TRIUMF has been developed to help optimize the efficiency and the personnel required

•High reliability is critical as we move towards the ARIEL era

Operational Model

Background

- What do we mean by "operation model"?
  - Overall scheme for accelerator operations taking into account operational constraints – beam delivery requirements, maintenance, shutdown, target exchanges, conditioning and startup, tuning, experimental needs, …
- Why do we need one?
  - ARIEL will provide the infrastructure to allow the delivery of three RIB simultaneously
  - An operation model will help determine infrastructure and resource requirements and experimental output

Present model

ITE	Su		Mo		Tu		We		Th		Fr		Sa	
Week	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1	Conditioning on-line without beam													
2	Conditioning on-line without beam													
3	Conditioning on-line without beam										Maint.	Start		Yield
4	Production (βNMR)				Beam dev.	Production (βNMR)							RIB development	
5	RIB development				Maint.	RIB development					Production (S1545)			
6	Production (S1545)			Production (βNMR)			Maint.	Production (βNMR)						Prod.
7	Prod. (Ops training)		Shields	Cooldown										
8	Cooldown				Tar-> HC	Target ex.	Conditioning station							
9	Conditioning station				Tar-> ITE	Conditioning on-line without beam								
10	Conditioning on-line without beam													
11	Cond. w/o beam		Maint.	Start	Maint.	Yield	Production (S1457)				Production (S1466)			
12	Production (S1466)				Maint.	Prod.	RIB development			Production (S1502)				

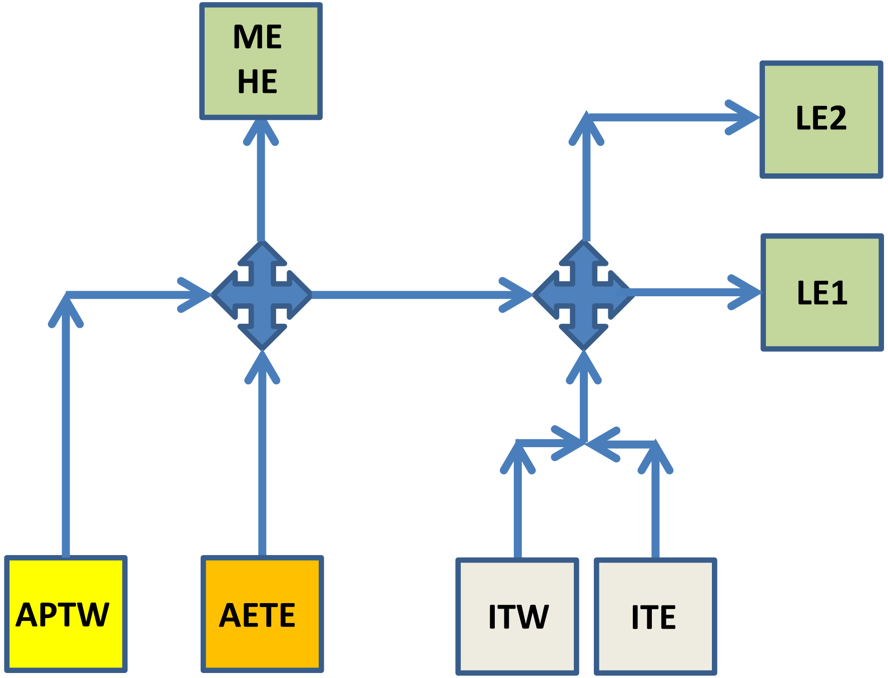
ITW	Su		Mo		Tu		We		Th		Fr		Sa	
Week	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1	Conditioning on-line with/without beam				Start			Yield	RIB development			Production (S1578)		
2	Production (S1578)				Beam dev.	RIB development		Production (L112)			Production (S1218)			
3	Production (L112/L122)				Maint.	Production (L112)		Production (Ops training)			Shields	Cooldown		
4	Cooldown													
5	Cooldown				Tar-> HC	Target exchange			Conditioning station					
6	Conditioning station						Tar-> ITW	Condition on-line without beam						
7	Cond. w/o beam		Maint.	Start	Beam dev.	Start	Yield	RIB development						
8	RIB development		Production		Maint.	Production (βNMR)								
9	Production (βNMR)				Maint.			Production (βNMR)			RIB development			
10	RIB development				Beam dev.	RIB development							Prod. (Ops training)	
11	Prod. (Ops training)		Shields	Cooldown										
12	Cooldown				Tar-> HC	Target ex.	Conditioning station							

Present model

- Operating schedules reflect demand for specific beams
  - Startup, operating lifetimes vary from target to target
  - Maintenance and development (RIB and cyclotron) vary from week to week
  - Schedule makeup – number of targets, etc. – varies from year to year
- No rhythm, but a measure of flexibility
  - Delivery may be rescheduled in the event of target or equipment failures
- Doesn’t scale well to multiple simultaneous RIB

RIB Operation in ARIEL Era

- Three RIB sources
  - 1 ISAC, 2 ARIEL
- Three experimental areas
  - 2 LE, 1 ME/HE
- One path from ARIEL to ISAC LE
  - All ME/HE beams will come from ARIEL when delivering three RIB simultaneously
- ARIEL and ISAC schedules need to align



New Model: RIB Factory

- ISAC and ARIEL share the same beamlines and experimental areas
  - Schedules are intertwined and highly constrained
- Solution: An assembly-line approach
  - Standardized target cycles and lifetimes
  - Regular maintenance and development periods
  - Frequent target changes to reduce impact of failures
  - Balanced resource loads – personnel and equipment
- Maintaining the target cycle becomes a higher priority than maintaining flexibility

The basics – target cycles

- Assume fixed target cycles:
  - ISAC:
    - Six weeks – three with ITE (ISAC Target East), three with ITW (West)
  - ARIEL:
    - Three weeks for each of AETE (ARIEL Electron Target East) and APTW (Proton Target West)
- Target startups are staggered so as not to overlap – one new target per week

Week	Exchange
1	ITE
2	APTW
3	AETE
4	ITW
5	APTW
6	AETE
7	ITE
8	APTW
9	AETE
10	ITW
11	APTW

Week by week target exchange schedule

Cyclotron schedule

- With fixed target cycles, fixed driver schedules - Cyclotron:
  - 12 hours for maintenance every Tuesday – may be shorter if maintenance needs allow
  - 24 hours for beam development every third Monday, coinciding with APTW target change
  - A 36-hour cryopanel defrost (I1 filament change) every ninth Monday, superseding beam development

	Target	Su		Mo		Tu		We		Th		Fr		Sa	
Week	Exchange	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1	ITE					Maint.									
2	APTW			Beam Development		Maint.									
3	AETE					Maint.									
4	ITW					Maint.									
5	APTW			Beam Development		Maint.									
6	AETE					Maint.									
7	ITE					Maint.									
8	APTW			Maint.	Maint.	Maint.									
9	AETE					Maint.									
10	ITW					Maint.									
11	APTW			Beam Development		Maint.									

- With fixed target cycles, fixed driver schedules – e-Linac
  - 12 hours for maintenance or development every Tuesday, coinciding with cyclotron maintenance
  - An additional 24 hours for maintenance or development every third Monday, coinciding with AETE target change
  - Maintenance and development – on an as-needed basis

	Target	Su		Mo		Tu		We		Th		Fr		Sa	
Week	Exchange	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1	ITE					Main/Dev									
2	APTW					Main/Dev									
3	AETE			Main/Dev	Main/Dev	Main/Dev									
4	ITW					Main/Dev									
5	APTW					Main/Dev									
6	AETE			Main/Dev	Main/Dev	Main/Dev									
7	ITE					Main/Dev									
8	APTW					Main/Dev									
9	AETE			Main/Dev	Main/Dev	Main/Dev									
10	ITW					Main/Dev									
11	APTW					Main/Dev									

ITE/ITW Schedules

ITE	Su		Mo		Tu		We		Th		Fr		Sa	
Week	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1	Condition on-line without beam				Maint.	Condition-beam		Start	Yield	Production				
2	Production		Beam dev/Maint		Maint.	TDS	Production							
3	Production				Maint.	Production								
4	Production				Shields	Cooldown								
5	Cooldown				Tar-> HC	Tar. X			Conditioning station					
6	Conditioning station				Cond->Tar	Condition on-line without beam								
7	Condition without beam				Maint.	Condition-beam		Start	Yield	Production				

ITW	Su		Mo		Tu		We		Th		Fr		Sa	
Week	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1	Production				Shields	Cooldown								
2	Cooldown				T> HC>X	Tar. X			Conditioning station					
3	Conditioning station				Cond->Tar	Condition on-line without beam								
4	Condition on-line without beam				Maint.	Condition-beam		Start	Yield	Production				
5	Production		Beam dev/Maint		Maint.	TDS	Production							
6	Production				Maint.	Production								
7	Production				Shields	Cooldown								

- ISAC operation alternates between ITE/ITW target stations
- Target changes are carried out while the other target station is producing
- Target start-ups are standardized with shifts dedicated for conditioning, start-up, yield and RIB development

ARIEL Stations – AETE/APTW

APTW	Su		Mo		Tu		We		Th		Fr		Sa	
Week	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1	Production				Maint.	Production								
2	Productio	Cooldown	Tar. X		Tar. X		Cond-beam		Start	Yield	Production			
3	Production				Maint.	TDS	Production							
4	Production				Maint.	Production								
5	Productio	Cooldown	Tar. X		Tar. X		Cond-beam		Start	Yield	Production			
6	Production				Maint.	TDS	Production							
7	Production				Maint.	Production								

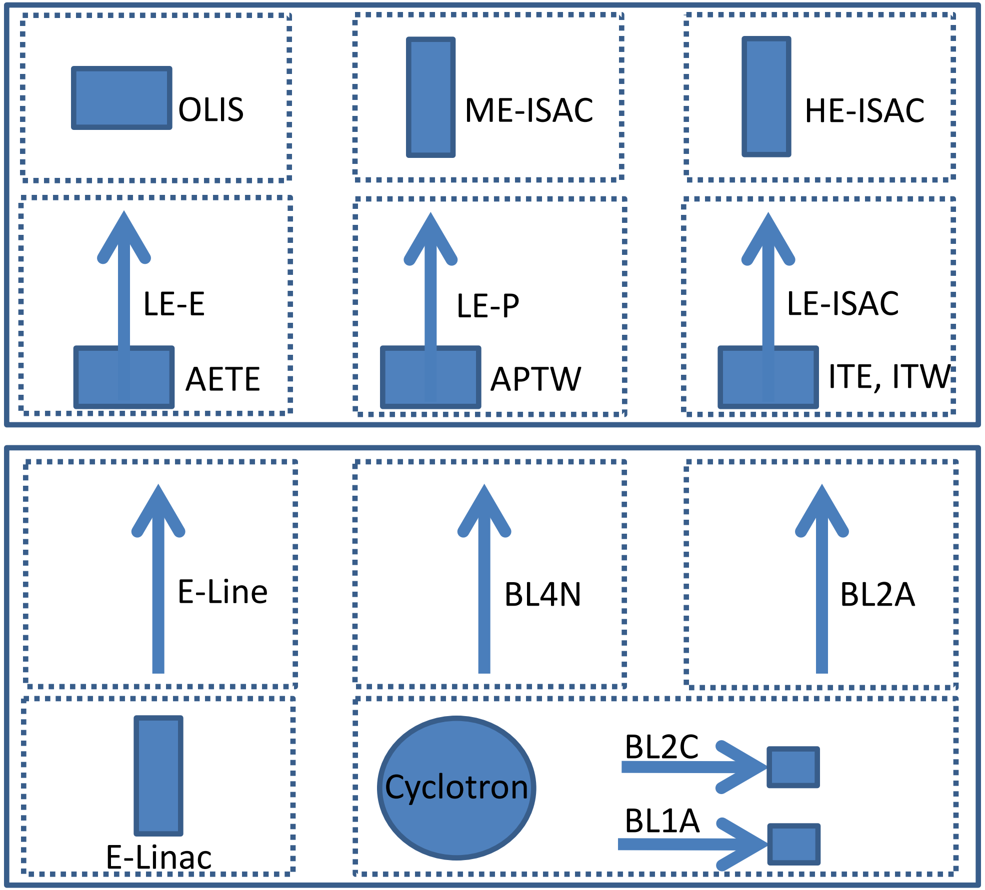
AETE	Su		Mo		Tu		We		Th		Fr		Sa	
Week	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1	Production				Maint.	TDS								
2	Production				Maint.	Production								
3	Productio	Cooldown	Tar. X		Tar. X		Cond-beam		Start	Yield	Production			
4	Production				Maint.	TDS								
5	Production				Maint.	Production								
6	Productio	Cooldown	Tar. X		Tar. X		Cond-beam		Start	Yield	Production			
7	Production				Maint.	TDS								

- Both stations operate in parallel
- Target changes require interrupting RIB production – goal is to exchange target within 5-day work week
- Target start-ups are standardized with shifts dedicated for conditioning, start-up yield and RIB development

Estimating RIB Hours

- Draft target cycles allow top-down estimates of RIB availability over a three-week period
- These can be extrapolated to full-year operation
- Assume standard overheads, procedures and reliability values
- Result: **9270 hrs/year**

	ITE/ITW	AETE	APTW
Total shifts	**42**	**42**	**42**
Cooldown	0	-1	-1
Target exchange	0	-4	-4
On-line conditioning	-2	-2	-2
Maintenance/driver dev.	-5	-2	-2
Startup	-1	-1	-1
Yield	-1	-1	-1
Target development	-1	-1	-1
Shifts available	**32**	**30**	**30**
LE exp'ts (number)	4.6	2	2
HE exp'ts (number)	--	1.8	1.8
Procedures	-5	-4	-4
RIB shifts/3 weeks	**27**	**26**	**26**
RIB hours/3 weeks	324	312	312
RIB hours/35 weeks	3780		3640
RIB hours/43 weeks		4472	
RIB hrs. w. reliability	**3024**	**3443**	**2803**

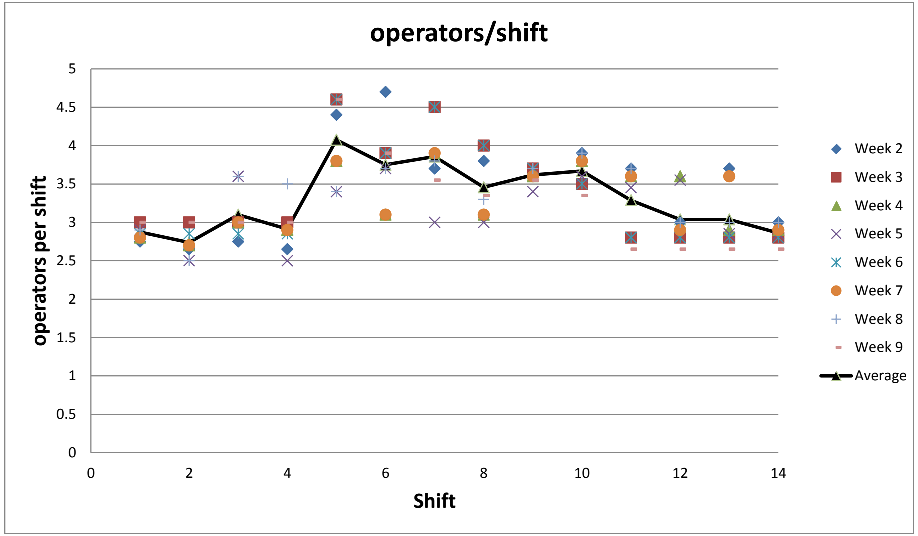


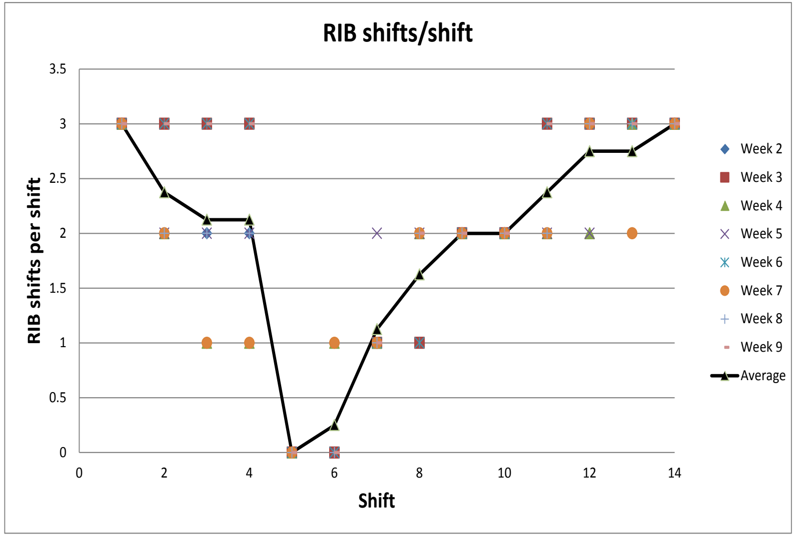
Assumptions:

- The complex is operated (initially) from two controls rooms ; the main control room (MCR) and the ISAC Control Room (ICR) – planning is in place for a new TRIUMF Control Centre (TCC)
- The MCR oversees the drivers (cyclotron and e-Linac) and the high intensity beamlines
- The ICR oversees operations of the target areas (ITE/ITW, AETE, APTW), all LE beamlines in ARIEL and ISAC, and the ISAC post-accelerator
- The eventual goal is to operate all facilities from a common control room

9-week strawman schedule

- Consider a nine-week strawman schedule – choose a realistic distribution of run lengths
  - Use two operators for base (one for MCR and one for ICR)
  - Add estimated operators needed for various activities
  - Estimations suggest 3 in MCR and 3 in ICR with expert support
  - In a unified TCC we estimate that 5 operators would be required





Strawman Schedule RIB hours

Week		Su		Mo		Tu		We		Th		Fr		Sa	
		AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
	Cyclotron	0.1	0.1	0.1	0.1	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	e-Linac	0.1	0.1	0.1	0.1	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		0.2	0.2	0.2	0.2	0.6	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
1	ITW							0.1	0	0.1	0.1	0.1	0.1	0.1	0.1
	ITE							0.8	0.1	0.1	0.1	0.1	0.1	0.8	0.1
	APTW							0.4	0.4	0.8	1	0.85	0.25	0.25	0.25
	AETE							0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		2.2	2.2	2.2	2.2	2.6	2.4	4.6	2.8	3.3	3.5	3.35	2.75	3.45	2.75
2	ITW	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	ITE	0.1	0.1	0.1	0.1	0.3	0.8	0.1	0.1	0.1	0.1	0.1	0.1	0.8	0.1
	APTW	0.25	0.25	0.25	0.25	0.3	0.3	0.8	0.9	0.4	0.4	0.4	0.4	0.4	0.4
	AETE	0.1	0	0.1	0	0.1	0	0.4	0.4	0.8	1	0.8	0.1	0.1	0.1
	OLIS					1		1							
		2.75	2.65	2.75	2.65	4.4	3.7	4.7	3.8	3.7	3.9	3.7	3	3.7	3
3	ITW	0.2	0.2	0.2	0.2	0.3	0.4	0.4	0.8	1	0.8	0.1	0.1	0.1	0.1
	ITE	0.1	0.1	0.1	0.1	0.1	0	0	0	0	0	0	0	0	0
	APTW	0.4	0.4	0.4	0.4	0.3	0.8	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	AETE	0.1	0.1	0.1	0.1	0.3	0.3	0.8	0.9	0.4	0.4	0.4	0.4	0.4	0.4
	OLIS					1		1							
		3	3	3	3	4.6	3.9	4.5	4	3.7	3.5	2.8	2.8	2.8	2.8
4	ITW	0.1	0.1	0.3	0.3	0.3	0.3	0.8	0.1	0.1	0.1	0.1	0.8	0.1	0.1
	ITE	0	0	0	0	0.1	0	0.1	0	0.1	0.1	0.1	0.1	0.1	0.1
	APTW	0.1	0	0.1	0	0.1	0	0.4	0.4	0.8	1	0.8	0.1	0.1	0.1
	AETE	0.4	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	OLIS					0.4									
		2.8	2.7	3	2.9	3.8	3.1	3.9	3.1	3.6	3.8	3.6	3.6	2.9	2.9
5	ITW	0.1	0.1	0.1	0.1	0.3	0.8	0.1	0.1	0.1	0.1	0.1	0.8	0.1	0.1
	ITE	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	APTW	0.1	0.1	0.1	0.1	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	AETE	0.4	0	0.1	0	0.1	0	0.4	0.4	0.8	1	0.85	0.25	0.25	0.25
	OLIS			1											
		2.9	2.5	3.6	2.5	3.4	3.7	3	3	3.4	3.6	3.45	3.55	2.85	2.85
6	ITW	0.1	0.1	0.1	0.1	0.3	0	0	0	0	0	0	0	0	0
	ITE	0.2	0.2	0.2	0.2	0.1	0.4	0.4	0.8	1	0.8	0.1	0.1	0.1	0.1
	APTW	0.1	0.1	0.1	0.1	0.3	0.8	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	AETE	0.25	0.25	0.25	0.25	0.3	0.3	0.8	0.9	0.4	0.4	0.4	0.4	0.4	0.4
	OLIS					1		1							
		2.85	2.85	2.85	2.85	4.6	3.9	4.5	4	3.7	3.5	2.8	2.8	2.8	2.8
7	ITW	0	0	0	0	0.1	0	0.1	0	0.1	0.1	0.1	0.1	0.1	0.1
	ITE	0.1	0.1	0.3	0.3	0.3	0.3	0.8	0.1	0.1	0.1	0.1	0.1	0.8	0.1
	APTW	0.1	0	0.1	0	0.1	0	0.4	0.4	0.8	1	0.8	0.1	0.1	0.1
	AETE	0.4	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	OLIS					0.4									
		2.8	2.7	3	2.9	3.8	3.1	3.9	3.1	3.6	3.8	3.6	2.9	3.6	2.9
8	ITW	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	ITE	0.1	0.1	0.1	0.1	0.3	0.8	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	APTW	0.1	0.1	0.1	0.1	0.3	0.3	0.9	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	AETE	0.4	0	0.1	0	0.1	0	0.4	0.4	0.8	1	0.8	0.1	0.1	0.1
	OLIS			1	1										
		2.9	2.5	3.6	3.5	3.4	3.7	3.8	3.3	3.7	3.9	3.7	3	3	3
9	ITW	0.2	0.2	0.2	0.2	0.3	0.4	0.4	0.8	1	0.8	0.1	0.1	0.1	0.1
	ITE	0.1	0.1	0.1	0.1	0.1	0	0	0	0	0	0	0	0	0
	APTW	0.4	0.4	0.4	0.4	0.3	0.8	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	AETE	0.1	0.1	0.1	0.1	0.3	0.3	0.85	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	OLIS					1									
		3	3	3	3	4.6	3.9	3.55	3.35	3.55	3.35	2.65	2.65	2.65	2.65
10	ITW	0.1	0.1	0.3	0.3	0.3	0.3								
	ITE	0	0	0	0	0.1	0								
	APTW	0.1	0	0.1	0	0.1	0								
	AETE	0.25	0.25	0.25	0.25	0.3	0.8								
	OLIS	2.65	2.55	2.85	2.75	3.4	3.5								
	Average	2.875	2.7375	3.1	2.9125	4.075	3.625	3.98125	3.45625	3.61875	3.66875	3.2875	3.0375	3.0375	2.8625

Colour Code

- move shield
- Cooldown
- Driver tuning
- Target to Hot Cell
- Maintenance
- target exchange
- hot cell to target
- condition
- condition w beam
- operate LE
- operate ME
- operate HE
- cyclotron
- e-Linac
- OLIS pre-tune
- LE tuning
- ME tuning
- HE tuning
- Yield
- Beam dev
- cond-stat
- TDS

Weeks		**35**	**35**	**43**
		ITE/ITW	**APTW**	**AETE**
Tot shifts	**1021**	**319**	**315**	**387**
LE shifts	635	319	206	110
ME shifts	113	0	27	86
HE shifts	273	0	82	191
Exp total	**119**	**54**	**31**	**33**
LE exp	88	54	19	14
ME exp	13	0	4	10
HE exp	17	0	8	10
Total hrs	**12251**	**3827**	**3780**	**4644**
LE hrs	7619	3827	2473	1319
ME hrs	1359	0	327	1032
HE hrs	3273	0	980	2293
RIB hrs	**9569**	**3061**	**2959**	**3549**
LE hrs	6095	3061	1979	1055
ME hrs	1019	0	245	774
HE hrs	2455	0	735	1720

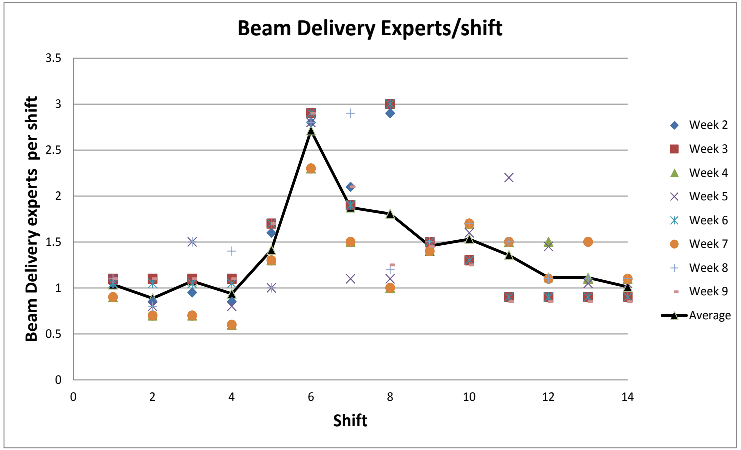
Other resources

Existing infrastructure

- ISIS
- Cyclotron
- BL1A, BL2C, BL2A
- ITE/ITW
- LEBT
- OLIS
- RFQ, DTL, ISAC-II
- MEBT, HEBT, DSB, SEBT

Added infrastructure

- E-Linac
- E-Line
- BL4N
- AETE/APTW
- New LEBT



Top down estimate of additional fractional effort required for full ARIEL operation. Need better estimates from parts count, existing time sheets, reliability estimates

Targets	Vacuum	Cryo	RF	Mag HW	DC PS	Diag	Controls	Safety	HV	RH	Sources
2.8	0.5	0.3	0.3	0.6	0.5	0.6	0.5	0.8	0.8	1.0	0.8

Table 6: Increased fractional effort over present technical load to operate the full ARIEL.

We will have to identify ways to improve efficiencies of target production, beam delivery (HLAs) and reliability to be able to afford to operate ARIEL

Other options

Within the Factory paradigm there is still room for some flexibility for targets where a shorter life cycle is preferred

- The fundamental assumption in all schemes is that only one target is started on any given week – flattens manpower load
- For the alternate cycles a two-week cycle would probably be the minimum given the effort and time required to bring a target on-line - For every two-week cycle there would also be a target area with a four-week cycle to maintain the one target per week pace.
- A few of the alternate cycles have been looked at in detail and while they are marginally less efficient than the three-week cycle they still produce more than 9000 hours of RIB per year.

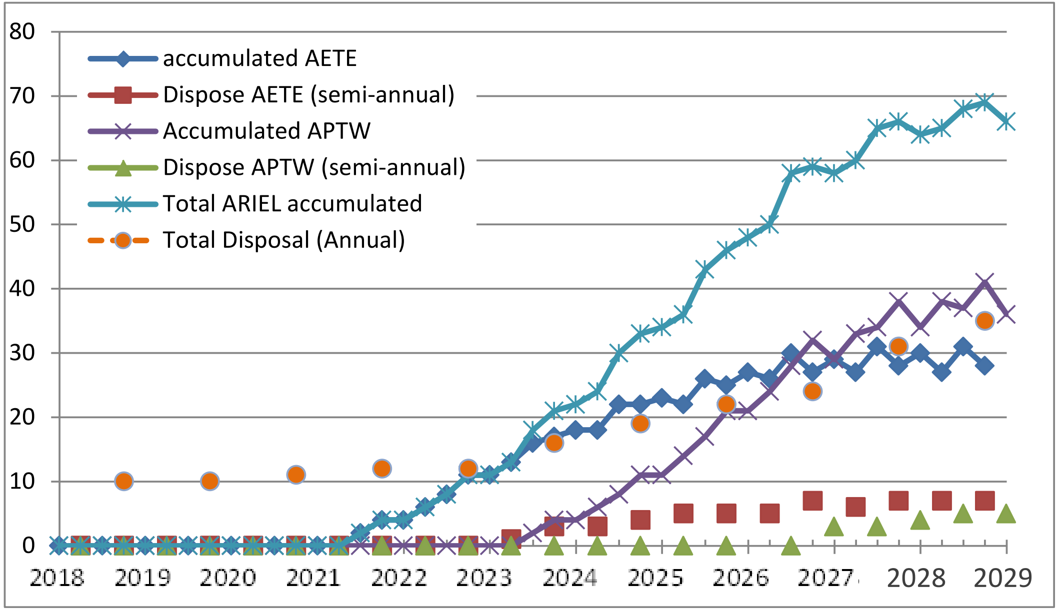
Week	Variant 1	Variant 2	Variant 3	Variant 4
1	AETE	AETE	AETE	AETE
2	ITW	ITW	ITW	ITW
3	APTW	APTW	APTW	APTW
4	AETE	AETE	AETE	AETE
5	ITE	APTW	APTW	APTW
6	APTW	ITE	ITE	ITE
7	AETE	AETE	AETE	AETE
8	ITW	APTW	APTW	APTW
9	APTW	ITW	AETE	ITW
10	AETE	AETE	ITW	AETE
11	ITE	APTW	APTW	ITE
12	APTW	ITE	AETE	APTW
13	AETE	AETE	ITE	AETE
14	ITW	APTW	APTW	ITW
15	APTW	ITW	AETE	APTW
16	AETE	AETE	ITW	AETE
17	ITE	APTW	APTW	ITE

Ramp up

Assumptions:

- ISAC waste disposal will continue as is but with more targets: 12/year vs. 9–10/year now
- ARIEL waste disposal will utilize a new storage vault and hot cell within the ARIEL complex
- ARIEL target bodies will be separated from their canisters after a decay period and prior to packaging for shipping to long-term storage
- Multiple target bodies will be packaged in each shipping flask to reduce cost as allowed by flask shielding capability and target activation

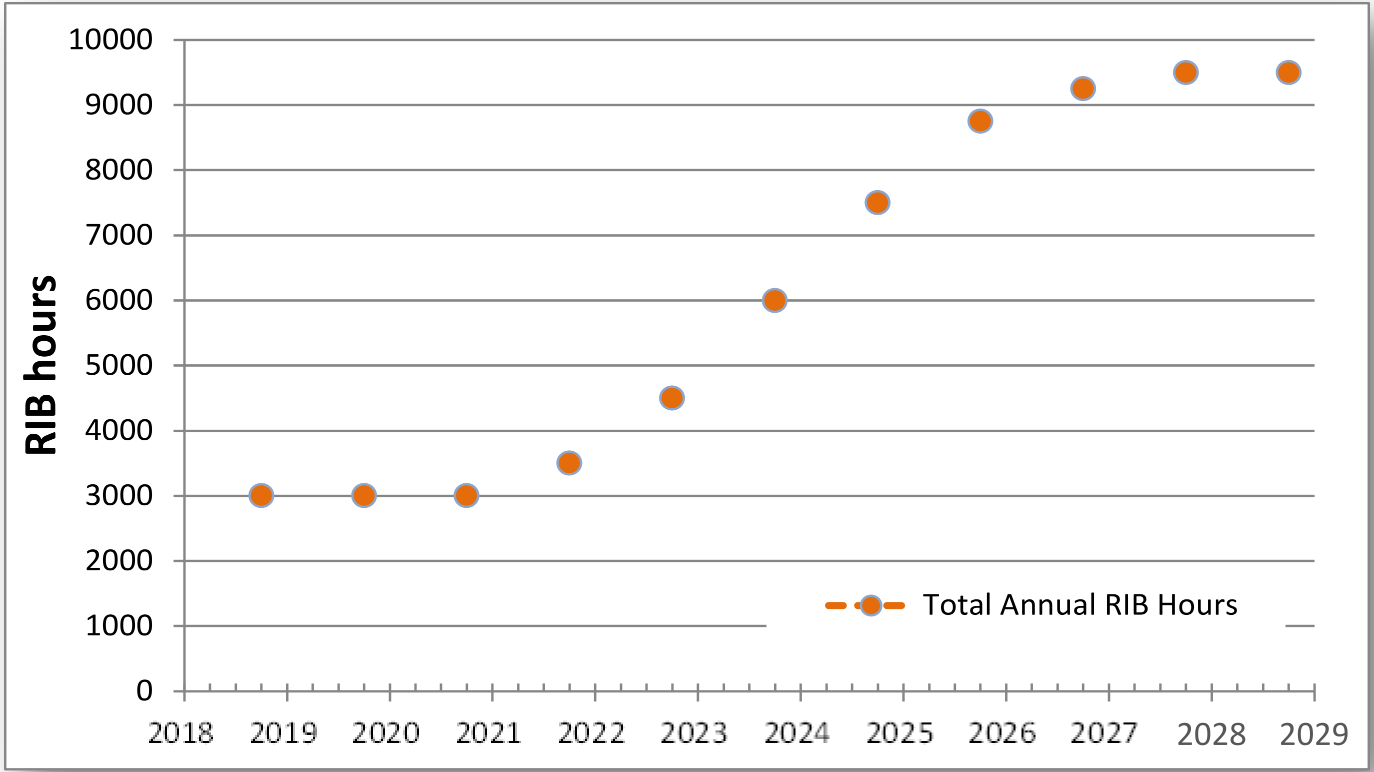
- ISAC:
  - 9–10 targets/yr now
  - 12 targets/yr by 2021
- AETE:
  - 4 targets in 2021
  - 14 targets/yr by 2026
  - 2 yrs storage/target
- APTW:
  - 4 targets in 2023
  - 12 targets/yr by 2027
  - 3.5 yrs storage/target



- ARIEL target storage saturates at 68 targets in 2029
- Consistent with a 72-unit decay storage vault

RIBs per year ramp up

- The number of RIB hours/year can be estimated based on the ramp up strategy

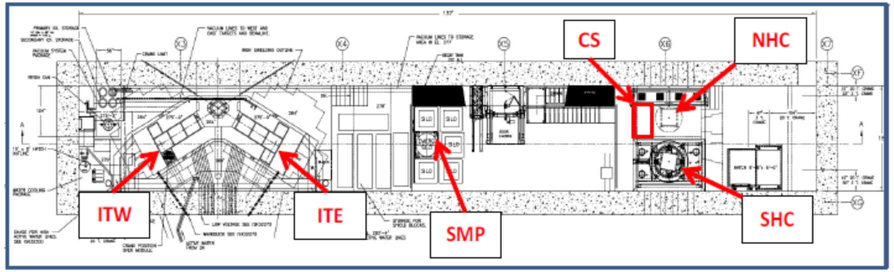


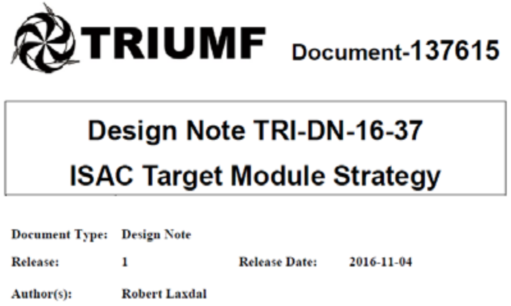
Summary of Operation Model

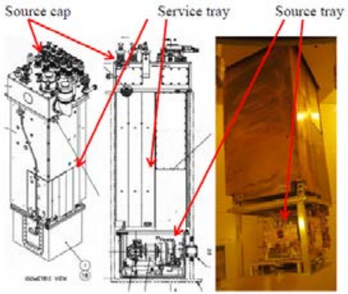
- What we (think we) know:
  - >9000 hours/year of RIB availability is reasonable
  - Operation can be maintained with 6 operators/shift working out of two control suites
  - Target waste can be managed within the planned infrastructure
- What do we still need?
  - Further work to determine operating costs and the number of technical staff required
  - Ways to improve efficiency (esp. in target production and beam delivery) and reliability
- **We have a model that we can use to inform design choices and operational planning.**

Reliability

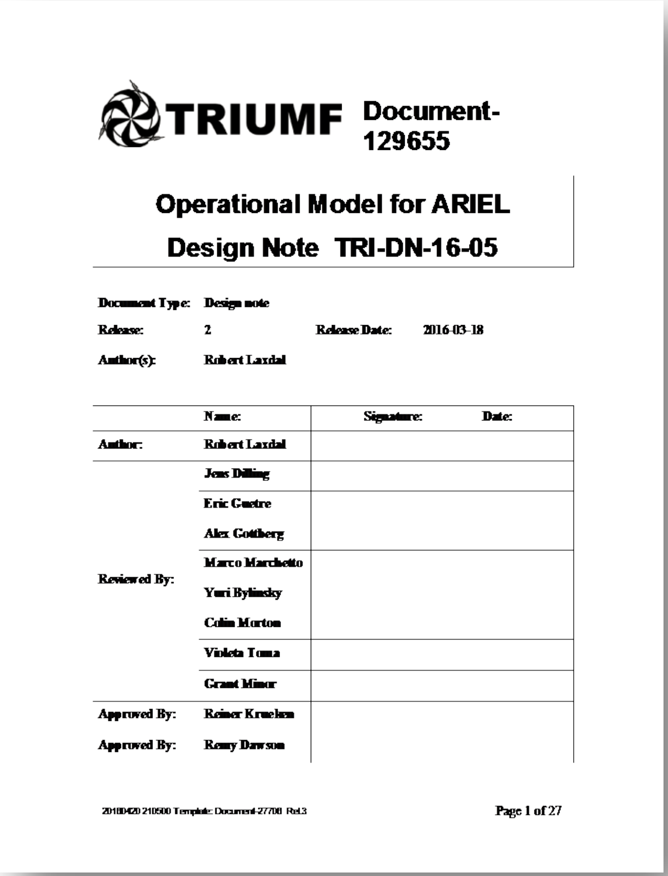
- A requirement of the Factory approach is that we need a high reliability and efficient target exchange in all target areas
- We must treat ISAC Refurbishing at the same priority as ARIEL
  - ISAC Target Hall upgrade
  - ISAC target module upgrade
- An analysis of the present status was done to help optimize the ISAC target module improvement plan
  - Conclusion – we need a new module in the rotation – **more in Oliver talk**







- An operation model for TRIUMF with ARIEL/ISAC is being developed
- “RIB Factory” approach:
  – Interleaved three-week target cycles
  – Fixed driver schedules
  – Regular weekly rhythm
  – Resource load balancing
- First order ARIEL ramp up estimated to help inform science potential, operational overhead and waste management requirements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Operational Model for ARIEL

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Author(s): Robert Laxdal

	Name:	Signature:	Date:
Author:	Robert Laxdal		
	Jens Dilling		
	Eric Guetre		
	Alex Gottberg		
Reviewed By:	Marco Marchetto		
	Yuri Bylinsky		
	Colin Morton		
	Violeta Toma		
	Grant Minor		
Approved By:	Reiner Kruecken		
Approved By:	Remy Dawson		

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Thank you!
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