

# Availsim

Software background and overview

[www.europeanspallationsource.se](http://www.europeanspallationsource.se)

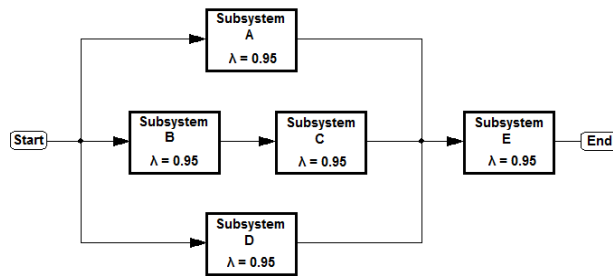
16-07-07

- Why a special made simulation?
- Old versions of AvailSim
- The new AvailSim

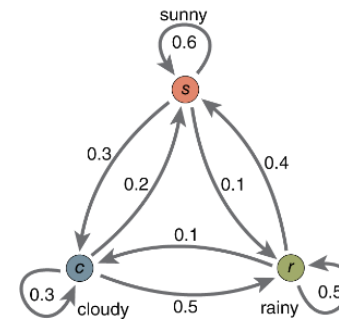
# Why a special made simulation?

# Ways of modelling – Analytical Calculations

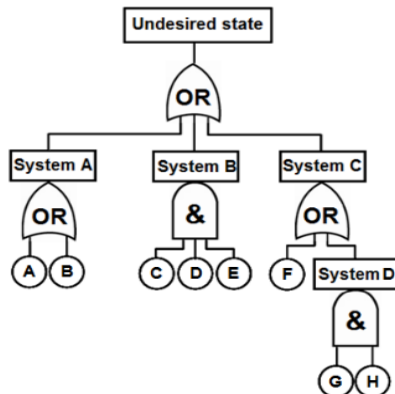
## RBD



## Markovs chain



## Fault Tree analysis



## Spreadsheet calculations

Date	UT1	Body	GRS	Dec	RA	SD	HP	Ext lat	lim
1	27/01/2007	07:55:22	Sol	289° 40.9'	18° 28.8'	28.97 50	16.24	0.16'	12.68.6027
2	27/01/2007	07:55:22	Luna	139° 30.9'	23° 36.2'	03.24 15	15.02	50.46'	65.26' (+)
3	27/01/2007	07:55:22	Joves	249° 5.9'					
4	27/01/2007	07:55:22	Venus	273° 23.3'	-13° 17.5'	22.68 42	3.08	0.10'	30.87
5	27/01/2007	07:55:22	Mars	528° 39.4'	23° 48.9'	18.39 48	3.02	0.06'	47.29
6	27/01/2007	07:55:22	Jupiter	359° 10.4'	-24° 41.7'	11.47 25	3.28	0.02'	30.49
7	27/01/2007	07:55:22	Saturn	59° 20.4'	19° 7.5'	03.42 10	3.17	0.02'	30.32
8	27/01/2007	07:55:22	Acenans	209° 38.9'	-33° 16.8'	02.58 33			
9	27/01/2007	07:55:22	Abhheian	173° 38.8'	18° 31.5'	04.38 21			
10	27/01/2007	07:55:22	Al-rah	514° 26.2'	59° 54.9'	12.54 22			
11	27/01/2007	07:55:22	Al-rah	39° 6.2'	49° 16.3'	13.47 56			
12	27/01/2007	07:55:22	Al-rah	169° 54.9'	-11° 1.8'	05.38 38			
13	27/01/2007	07:55:22	Al-rah	171° 18.7'	-28° 41.1'	13.24 08			
14	27/01/2007	07:55:22	Al-rah	242° 52.7'	23° 7.9'	03.08 44			
15	27/01/2007	07:55:22	Al-rah	204° 17.1'	0° 53.0'	19.51 07			
16	27/01/2007	07:55:22	Al-rah	314° 3.9'	13° 0.5'	11.15 00			
17	27/01/2007	07:55:22	Al-rah	282° 7.8'	8° 18.1'	02.38 46			
18	27/01/2007	07:55:22	Al-rah	128° 21.1'	23° 13.8'	07.45 47			
19	27/01/2007	07:55:22	Al-rah	142° 41.9'	-19° 43.9'	03.45 26			
20	27/01/2007	07:55:22	Al-rah	49° 46.2'	-14° 12.9'	13.25 04			
21	27/01/2007	07:55:22	Al-rah	229° 46.9'	33° 42.1'	18.37 08			
22	27/01/2007	07:55:22	Al-rah	228° 14.7'	16° 4.4'	14.53 16			

- **Commercial**

- Mainly based on RBD
- Productivity oriented (usually)
- Limited to the main costumers' needs
- Not enough for some needs of accelerator facilities (my experience)



- **Special made**

- AvailSim (the only one that I know of for particle accelerators)

# Old versions of AvailSim

*AvailSim 1.0 and 2.0*

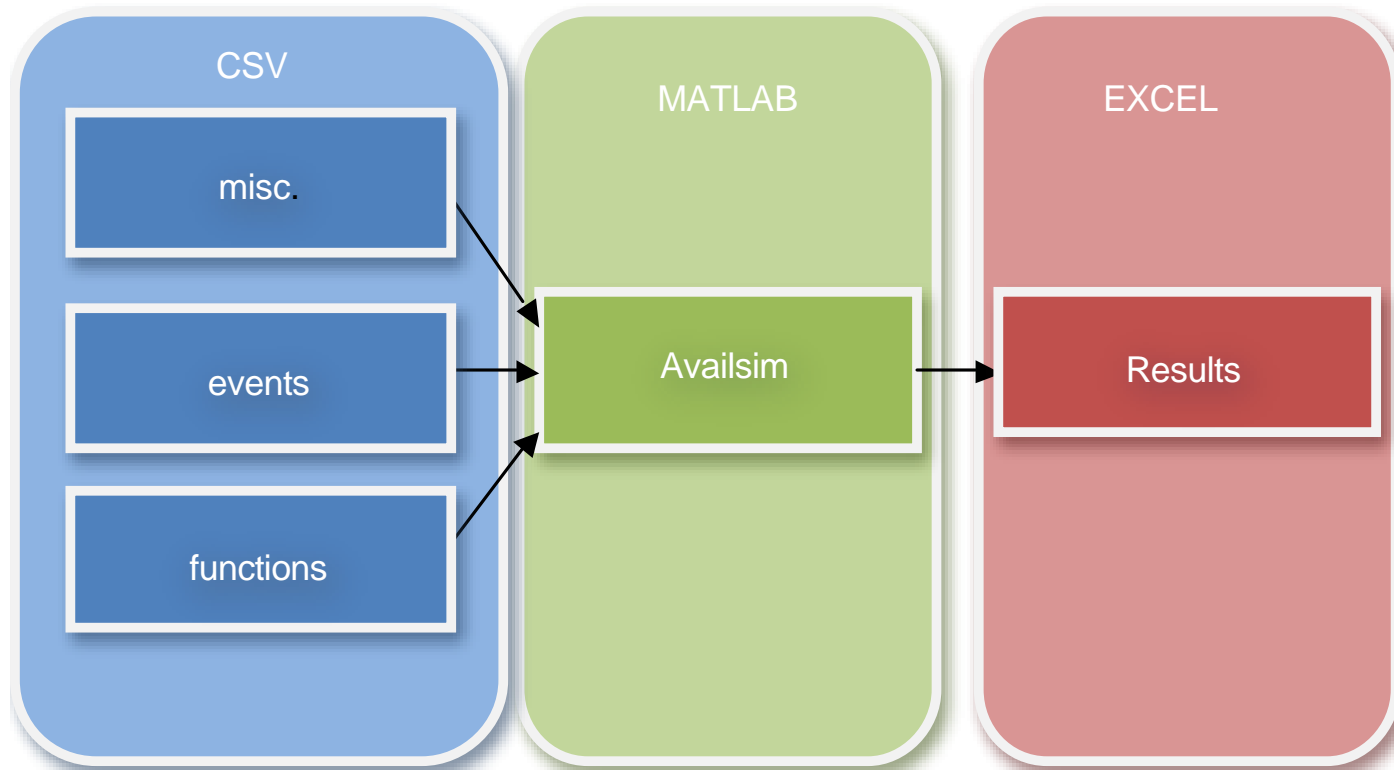
- Simulated the availability and beam characteristics of an accelerator
  - Continuous failure of components during operation and the effect those events have on accelerator performance
- Include complexities not possible in commercial tools such as:
  - Smart” repairs
    - Detects parameter degradation, repairing parameters with too high degradation
  - Scheduled maintenance shutdown
    - Accounts for an annual maintenance period, performing repairs on the accelerator
  - Recovery
    - Accelerator recovery proportional to the downtime
  - Kludge repairs
    - Faster ”tweaks”, enabling continuous operation
- Written in Matlab

# Availsim 2.0

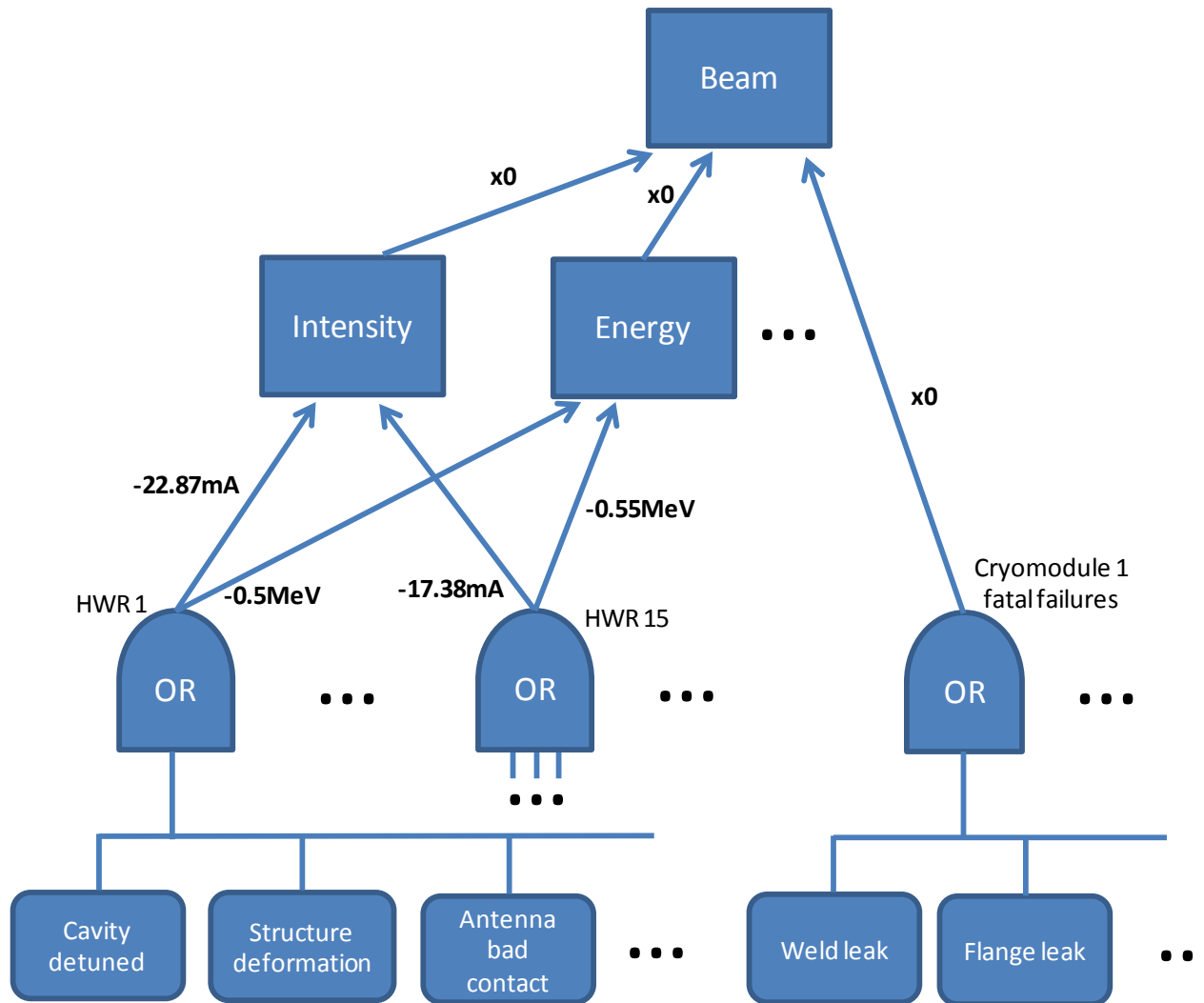
- Tailor-made for IFMIF RAMI analysis
- It has Availsim 1.0 features and in addition:
  - Different failure modes for each component
  - Every component is treated individually
  - Group events (failure of a component should not always degrade further the function provided by the system in which it belongs)
  - Introduced "Functions" to enable complex degraded operations and redundancies (functions net)



# AvailSim 2.0 overview



# AvailSim 2.0 example



# AvailSim 2.0 inputs - events

facility	system	subsystem	name	quantity	location	id	mtbf	mttr	access	recovery	mdt	hotrepair	numtorepair	function affected	calc	degradation	codegroup
1.00	Injector (& LEBT)	Source and Extraction system	Magnatron	1.00	V	1IVRBMNG001	5.555556e+04	1	24	1	26	0.00	1.00	Beam	Mult	0	I-SOURCE-EXTR1
1.00	Injector (& LEBT)	Source and Extraction system	Wave guides	1.00	V	1IVIRWAG001	1000000	24	24	15	63	0.00	2.00	Beam	Mult	0	I-SOURCE-EXTR1
1.00	Injector (& LEBT)	Source and Extraction system	RF window	1.00	V	1IVIRRW001	6.369427e+05	10	24	15	49	0.00	2.00	Beam	Mult	0	I-SOURCE-EXTR1
1.00	Injector (& LEBT)	Source and Extraction system	Cooling channels	1.00	V	1IVWWCG001	50000000	8	24	3	35	0.00	2.00	Beam	Mult	0	I-SOURCE-EXTR1
1.00	Injector (& LEBT)	Source and Extraction system	Cooling channels	1.00	V	1IVWWCG002	50000000	8	24	3	35	0.00	2.00	Beam	Mult	0	I-SOURCE-EXTR1
1.00	Injector (& LEBT)	Source and Extraction system	Switch Flow	1.00	V	1IVWBFSE001	2.941176e+06	4	24	3	31	0.00	2.00	Beam	Mult	0	I-SOURCE-EXTR1
1.00	Injector (& LEBT)	Source and Extraction system	Switch temperature	1.00	V	1IVWBSWE001	5.555556e+06	5	24	3	32	0.00	2.00	Beam	Mult	0	I-SOURCE-EXTR1
1.00	Injector (& LEBT)	Source and Extraction system	Plunger	1.00	V	1IVBIPRG001	1.020408e+07	3	24	11	38	0.00	2.00	Beam	Mult	0	I-SOURCE-EXTR1
1.00	Injector (& LEBT)	Source and Extraction system	Screw	1.00	V	1IVBISRG001	10000000	2	24	11	37	0.00	2.00	Beam	Mult	0	I-SOURCE-EXTR1
1.00	Injector (& LEBT)	Source and Extraction system	Step motor	1.00	V	1IVBISMP001	8.000000e+05	1	24	11	36	0.00	2.00	Beam	Mult	0	I-SOURCE-EXTR1
1.00	Injector (& LEBT)	Source and Extraction system	Coils	1.00	V	1IVBBOOG001	1.972387e+07	24	24	11	59	0.00	3.00	Beam	Mult	0	I-SOURCE-EXTR1
1.00	Injector (& LEBT)	Source and Extraction system	Coils	1.00	V	1IVBBOOG002	1.972387e+07	24	24	11	59	0.00	3.00	Beam	Mult	0	I-SOURCE-EXTR1

# AvailSim 2.0 inputs - functions

facility	type	function	design value	min value	action affected	mult/add 1	degradation 1	Level 1
A1	0	DBPM	16	13	Beam	Mult	0	0
A1	0	DCBPM	21	17	Beam	Mult	0	0
A1	0	DBLoM	57	40	Beam	Mult	0	0
A1	0	DMLM	70	30	Beam	Mult	0	0
A1	0	DDCCT	8	6	Beam	Mult	0	0
A1	0	HQuad25	2	2	Intensity	Set	87	5
A1	0	HTrip1BTR	3	2	Beam	Mult	0	0
A1	0	HTrip2BTR	3	2	Beam	Mult	0	0
A1	0	HTrip1V	3	2	Beam	Mult	0	0
A1	0	HSteerH25	6	5	Intensity	Set	115	3
A1	0	HSteerV25	6	5	Intensity	Set	115	3
A1	0	HSteerH	20	17	Beam	Mult	0	0

# AvailSim 2.0 inputs - miscellanea

- Maintenance crew
- Simulation hours
- Access times
- Extra repair factor
- Scheduled maintenance frequency, duration...
- Possible cancellation of scheduled maintenance
- Simulation trace file detail
- Simulation seed



# AvailSim 2.0 outputs (events)



name	facility	ID	nfailuresnotignored	nfailurescausingdown	downhourscaused	repair hours incremented	oportunity repair hours	nfailuresigned
Titanium sublimation pump	2	2MBOV TPG003	10,325	0,4875	23,39082234	20,39375	190,09375	2,475
Solenoids (inner and outer)	1	1SVYBS CG015	0,075	0	0	0	137,55	0,0125
Solenoids (inner and outer)	1	1SVYBS CG009	0,075	0	22,95818596	0	114,625	0
Bad soldering (antena bad contact)	2	2SVYR WEG00 2	0,05	0	0	0	91,35	0,025
Steerers (H)	2	2SVYBS TG027	0,0375	0,0125	10,30713998	0	69,225	0
Solenoids (inner and outer)	1	1SVYBS CG004	0,05	0	0	0	68,775	0
Solenoids (inner and outer)	1	1SVYBS CG008	0,0375	0	0	0	68,775	0
Solenoids (inner and outer)	1	1SVYBS CG014	0,05	0,0125	5,636058346	0	68,775	0
Solenoids (inner and outer)	2	2SVYBS CG015	0,05	0,0125	4,537969032	0	68,775	0
Bad soldering (antena bad contact)	2	2SVYR WEG03 0	0,05	0	0	0	68,5125	0
Bad soldering (antena bad contact)	1	1SVYR WEG00 3	0,0625	0	0	0	68,5125	0,0125
Bad soldering (antena bad contact)	2	2SVYR WEG02 0	0,0375	0	0	0	68,5125	15 0

- Advantages:
  - Tailor-made for accelerator availability analysis
    - Allows multiple degrade modes of operation
    - Flexible (maintenance offset/component locations/redundancies..)
  - Best corresponds to reality



- Disadvantages
  - Very specific for IFMIF
  - Hard to manage/understand (Even with in-depth knowledge)
  - Not modular
  - Require Matlab license



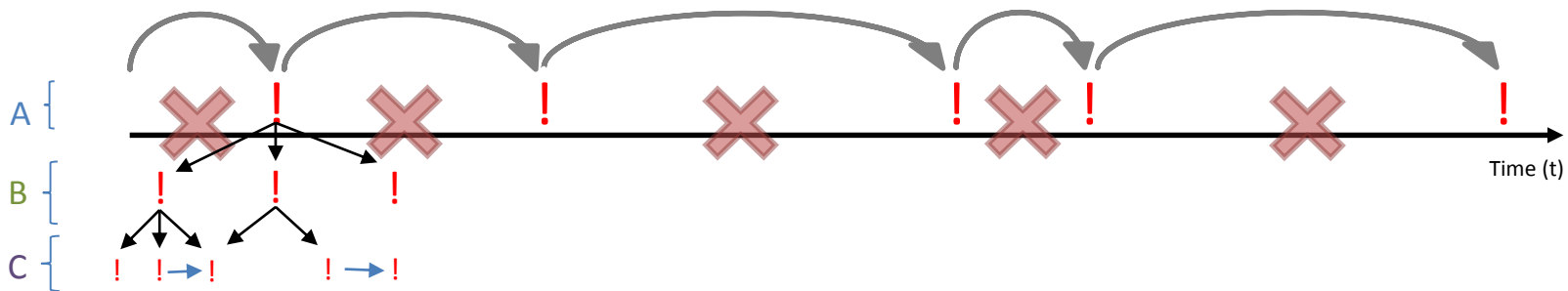
# New AvailSim

# New AvailSim introduction

- Being developed at ESS at the moment
- Right now finishing the core of the software
- The idea is to make it open, easy to use and adaptable if needed to specific needs

# New AvailSim – simulation

- Discrete event simulation (DES)
  - Events occur at a particular instant in time, marking a change in the system
  - Between consecutive events, no changes in the system is assumed to occur (enables "jumping")
  - Three-phased approach (A, B and C-events) (Pidd, 1998)



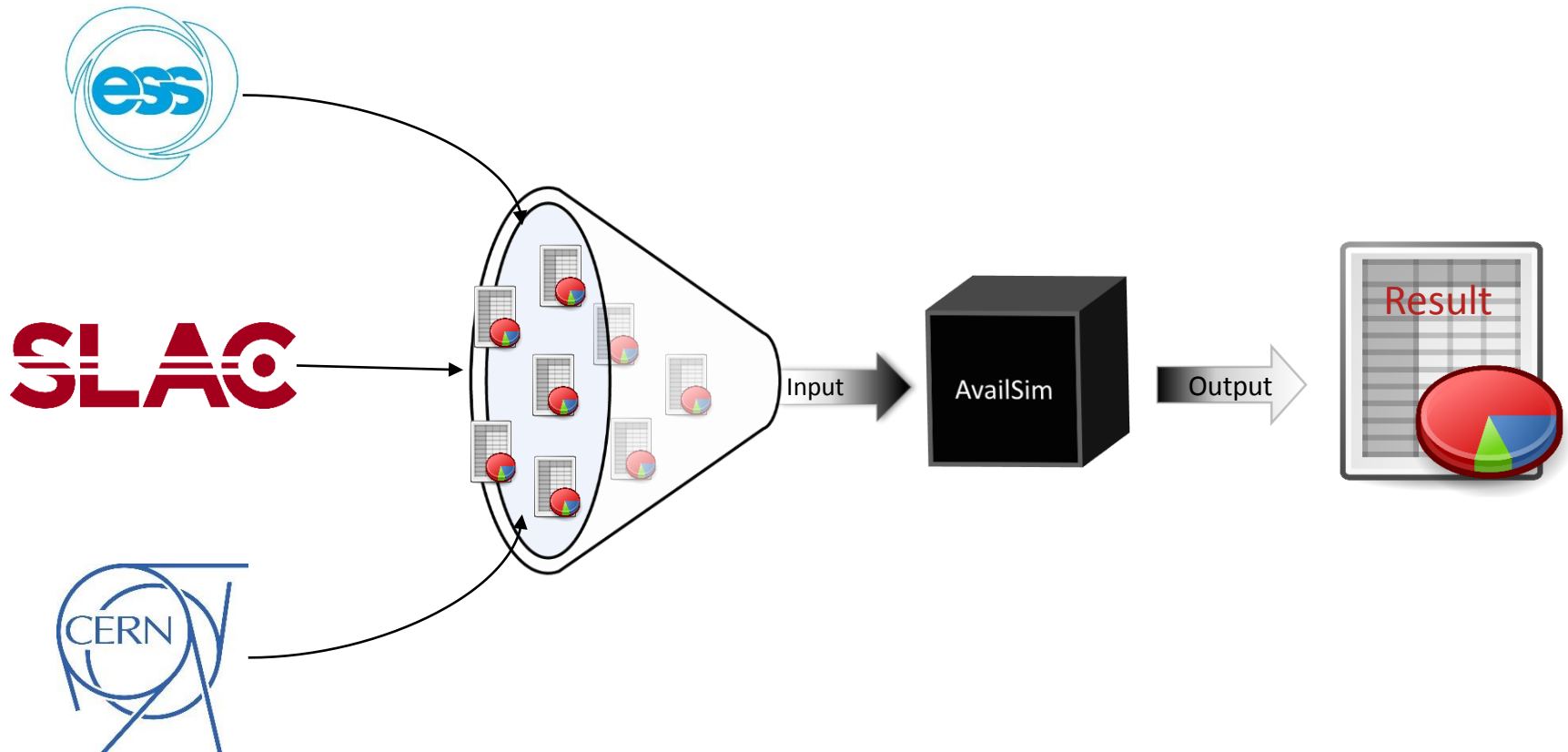
# New AvailSim - programming language



VS



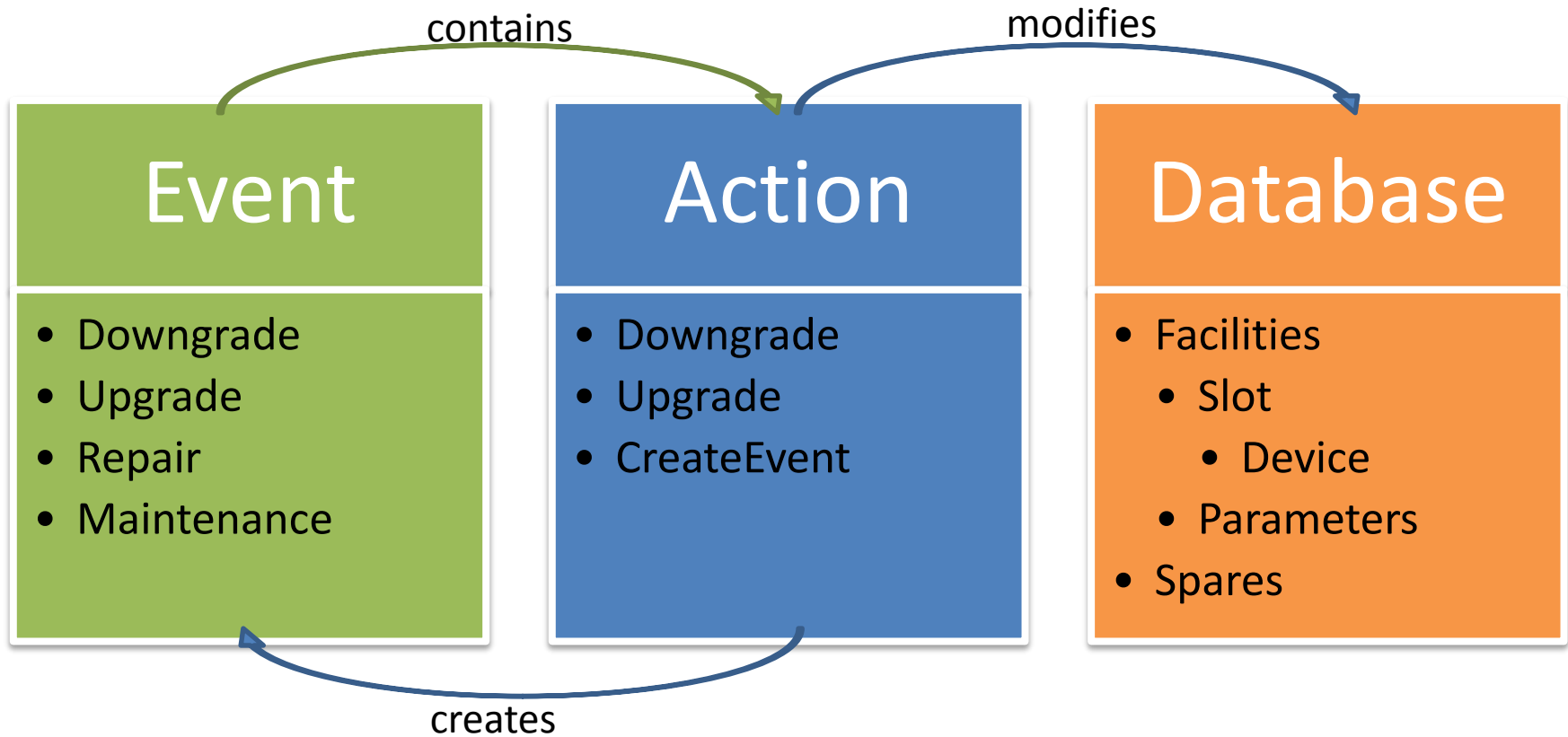
# New Availsim - Overview

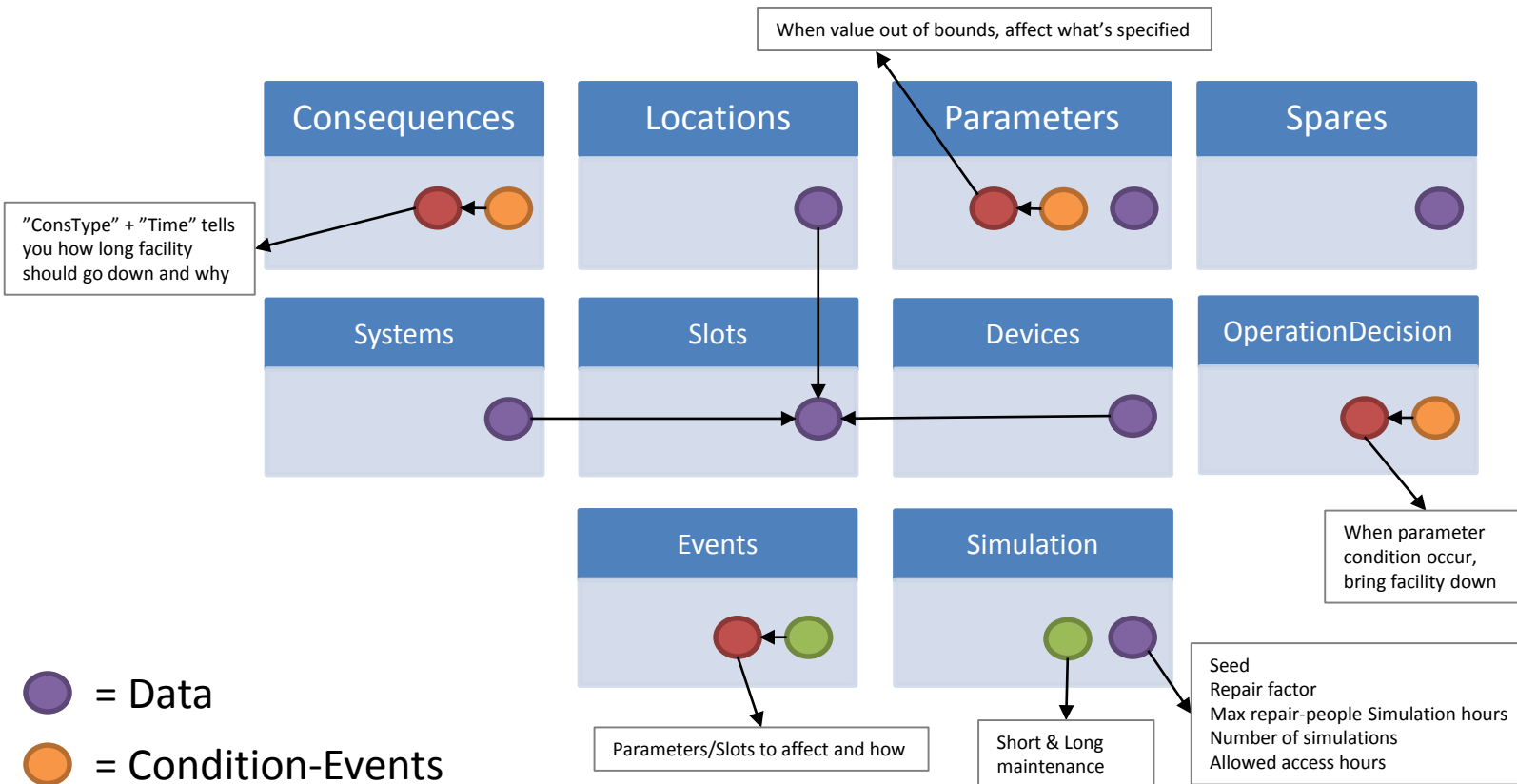


# Input files with examples

<b>Consequences</b> <ul style="list-style-type: none"><li>• Retune accelerator</li></ul>	<b>Locations</b> <ul style="list-style-type: none"><li>• Tunnel</li><li>• ...</li></ul>	<b>Parameters</b> <ul style="list-style-type: none"><li>• Beam power</li><li>• ...</li></ul>	<b>Spares</b> <ul style="list-style-type: none"><li>• PS</li><li>• ...</li></ul>
<b>Systems</b> <ul style="list-style-type: none"><li>• RF to Cavity 11</li><li>• ...</li></ul>	<b>Slots</b> <ul style="list-style-type: none"><li>• Klystron 11</li><li>• ...</li></ul>	<b>Devices</b> <ul style="list-style-type: none"><li>• Klystron A22B</li><li>• ...</li></ul>	<b>OperationDecision</b> <ul style="list-style-type: none"><li>• Stop if P&lt;50%</li><li>• ...</li></ul>
	<b>Events</b> <ul style="list-style-type: none"><li>• Klystron A22B gun failure</li></ul>	<b>Simulation</b> <ul style="list-style-type: none"><li>• 40 years</li><li>• ...</li></ul>	

# Overview of the software structure

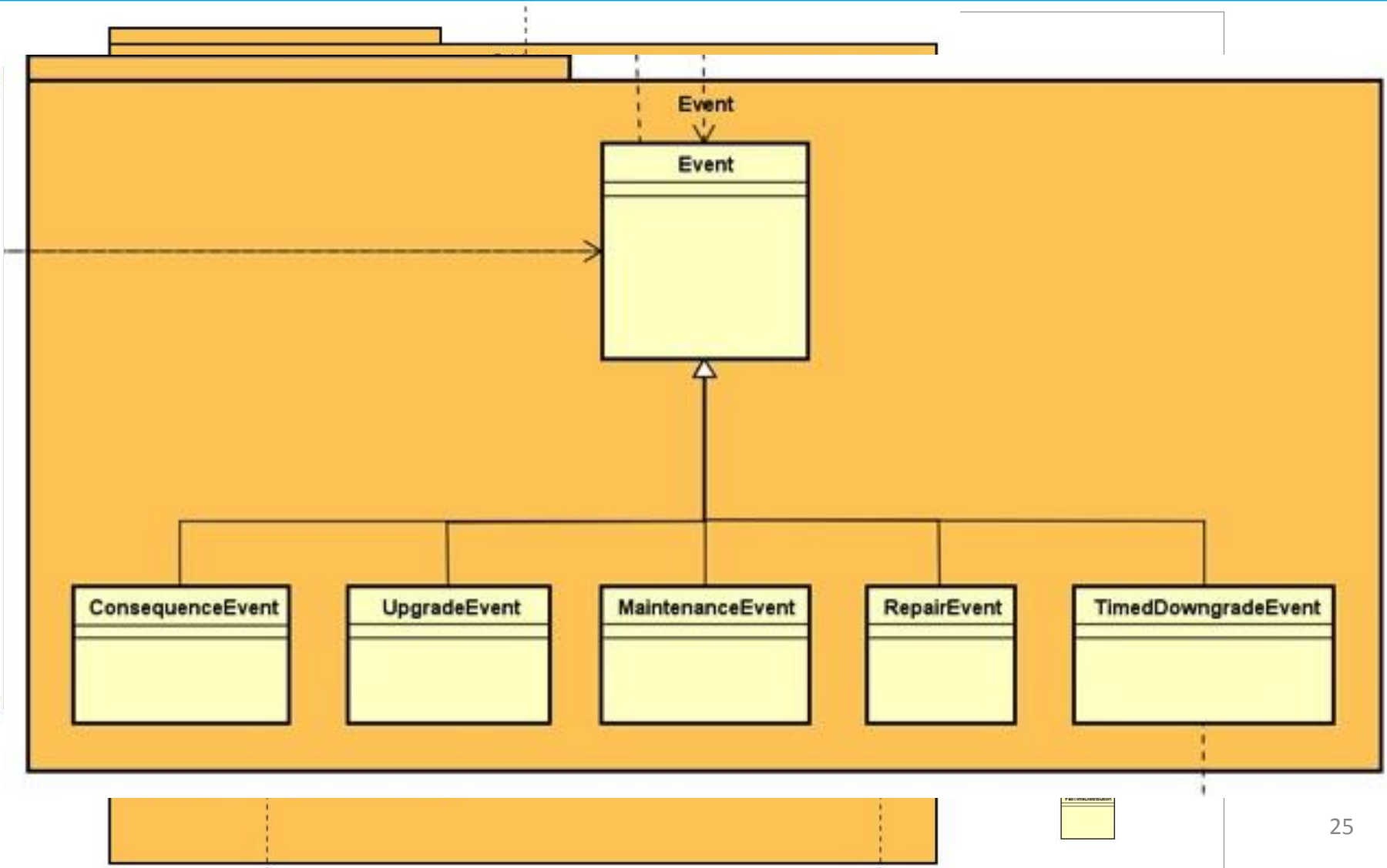




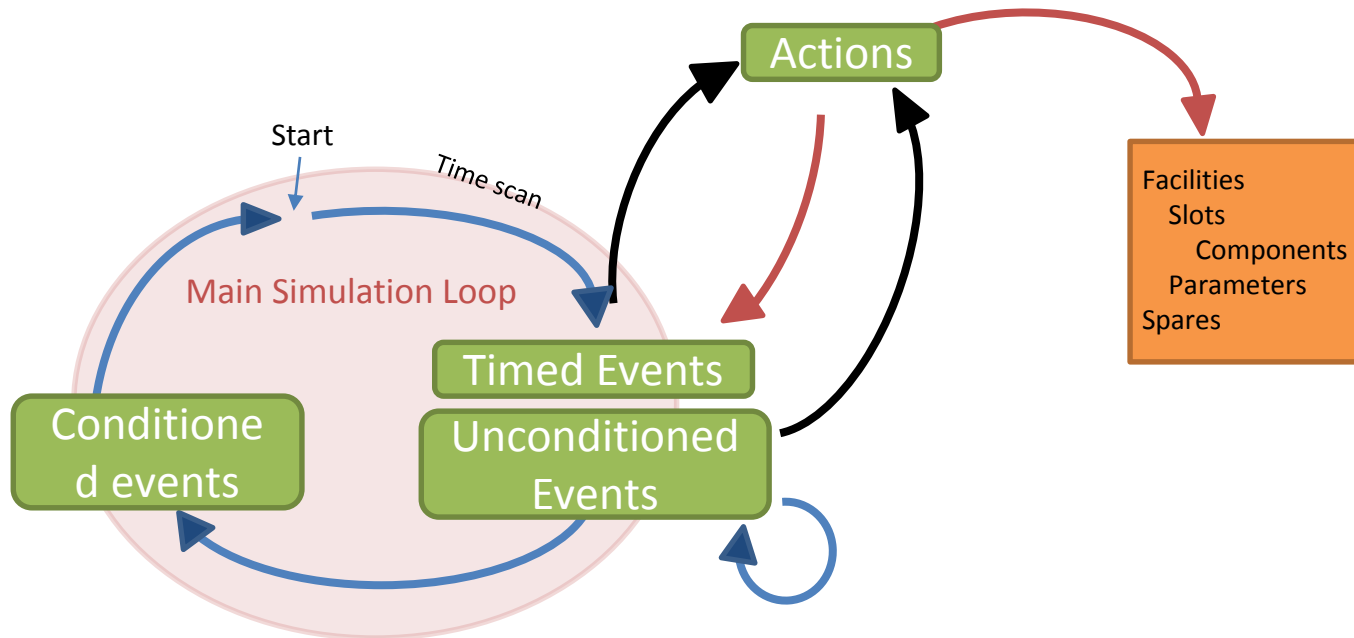
- = Data
- = Condition-Events
- = Time-Events
- = Actions



# Software UML Class Diagram

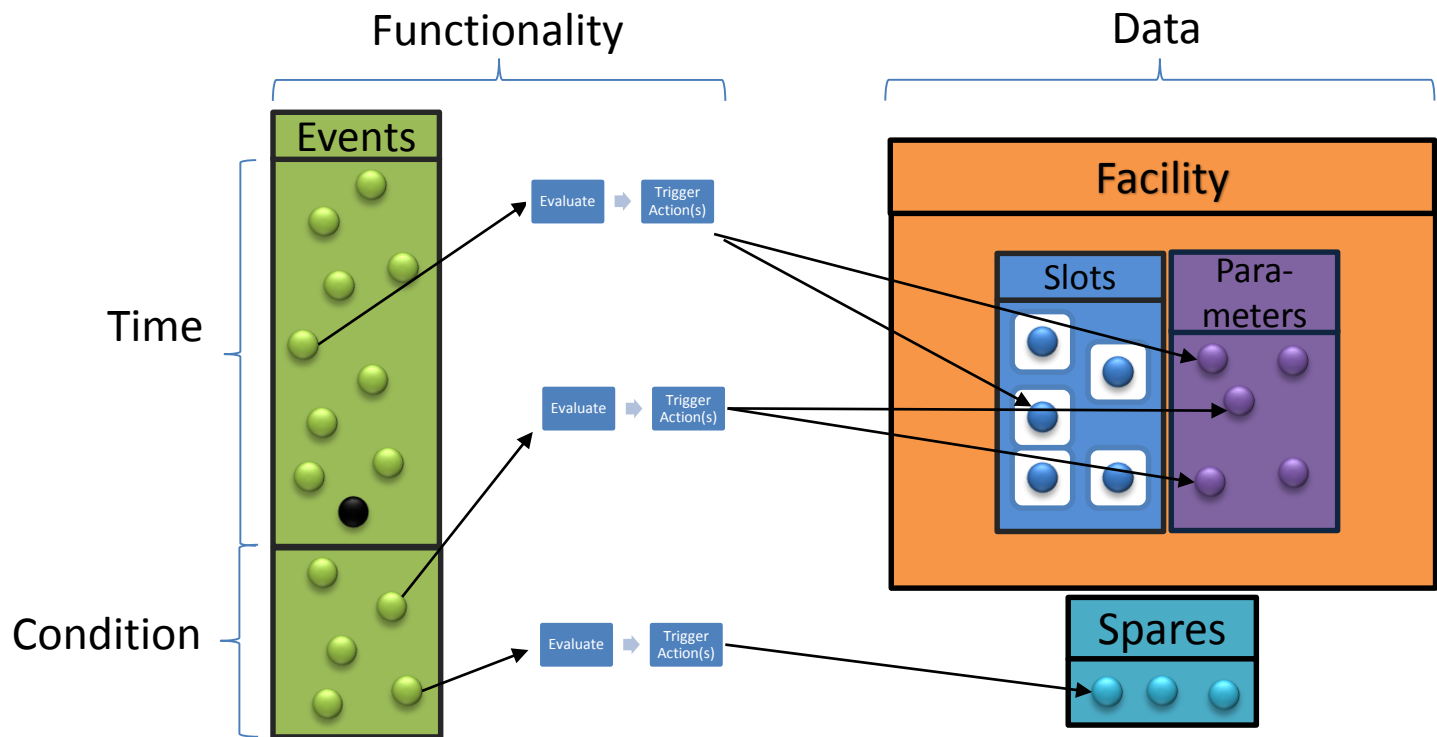


# Idea - overview



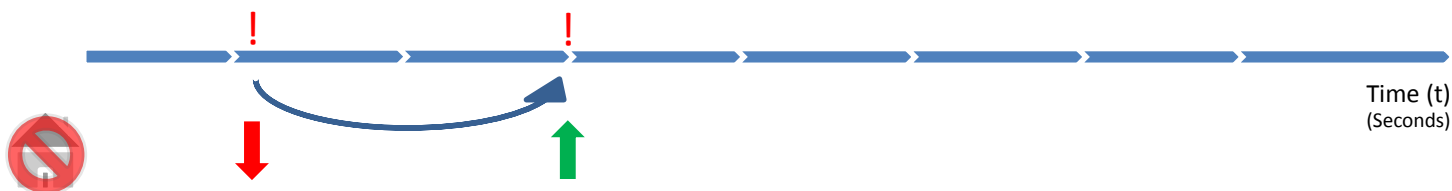
1. Prepare the software for upcoming simulation by e.g. populating the database, seed the randomizer, initiate event creation, etc
2. Gather all events and executes them accordingly throughout the simulation. First, A and B events are being executed (the events unconditionally occurring in this time). Secondly, the C events are executed until no more condition event occurs. This is corresponding to the Availsim2.0 "main loop"
3. Lastly, once we exceed the simulation hours, the Simulation class will compile a result class consisting of important data gathered throughout the simulation.

# Example scenario



### Description of the example

- An event “klystron gun fails” is activated
- Klystron 11 slot is off and parameter RF is 0
- Beam parameters changed, accelerator down
- Maintenance action, Klystron spare needed
- New time event created to upgrade
- Events have a new time and parameters and slots fixed

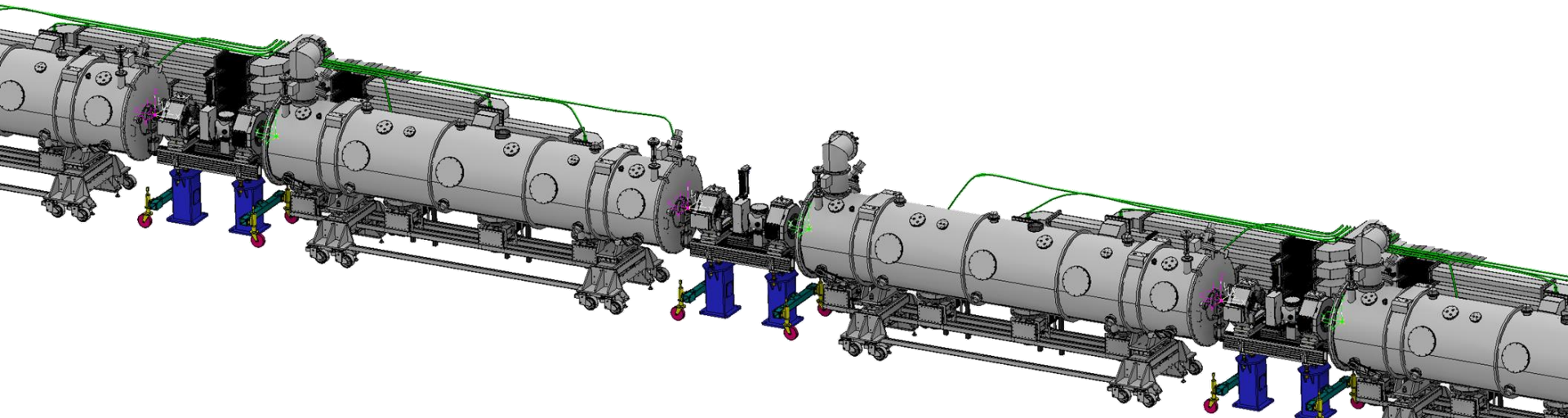
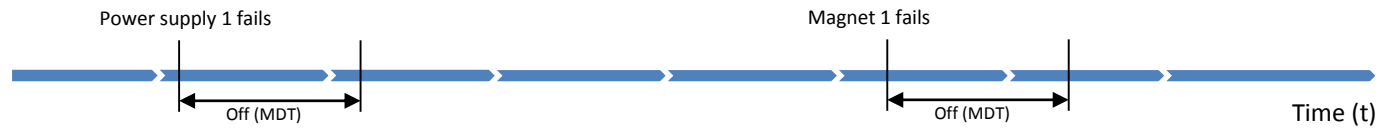
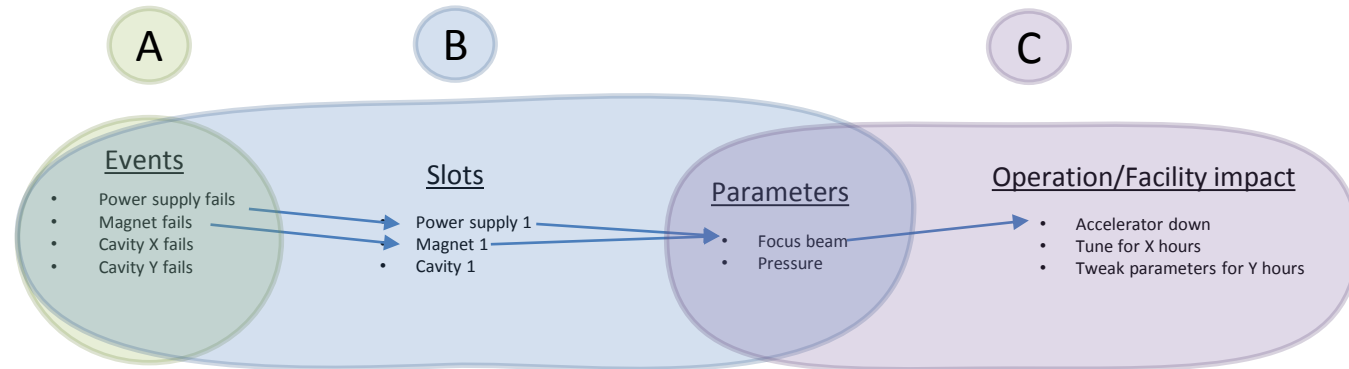


- **Devices and events**
  - Name, facility, ID, Location, System etc..
  - Failures ignored/not ignored
  - Down hours caused
  - Times occurred
- **Parameter**
  - Name, Facility, Consequence, Values etc..
  - Mean value
  - Times down (above/under threshold)
- **Consequences**
  - Down hours caused
  - Times occurred
- **Operation Decision**
  - Times down (above/under threshold)
  - Parameters responsible
- **Facility**
  - Hours in operation
  - Downtime hours
  - Maintenance hours
  - Times accessed
  - Operational availability
  - Hardware availability
- **History**
  - Logs every action

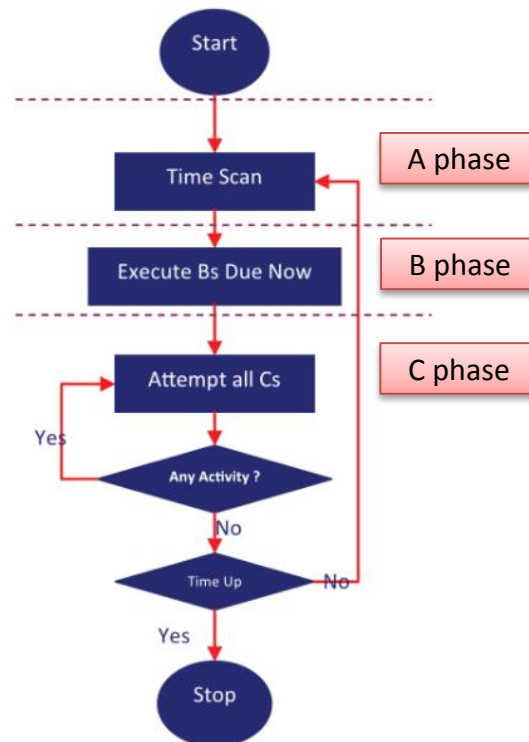
- There is still a lot of work to be done regarding:
  - Further develop simplified modules (e.g. spares, manpower, failure distributions...)
  - Standard input deck and translation into AvailSim inputs
  - Specific features for ESS, CERN...
  - Possible graphical interface
  - Results plotting, querying, etc.

# Questions?

# New Availsim



# The three-phase method



A three-phase executive (Pidd, 1998)