MPEX High Level Commissioning

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Outline of this talk

- Commissioning and high-level commissioning goals
- Performance/availability/reliability increase over time
- Major operational risks
- Capability increase and impact on science program
- Suggestions for staged science program

Preliminary MPEX Key Performance Parameters as agreed with FES

- KPP 1: ***Demonstration of First Plasma*** for one minute operation, with:
  - Electron density, n_e = 1e19 m^{-3}
  - Electron and ion temperatures, $T_e = T_i$ = 5 eV
  - Magnetic field at the target, B_{target} = 0.5 T
- KPP2: ***Demonstration of the magnet system*** to full magnetic field for 4 hours.

MPEX shall be designed to achieve UPPs to fulfill mission need

Parameter	Mission Need	MPEX NPP	MPEX UPP
n_e target	>10^{19} m^{-3}	5 x 10^{19} m^{-3}	10^{21} m^{-3}
T_e target	up to 15 eV	12 eV	15 eV
T_i target	up to 15 eV	12 eV	20 eV
B target	1 T	1 T	1 T
Plasma diameter	10 cm	3 to 10 cm	3 to 10 cm
Γ_I target	> 10^{23} $m^{-2}s^{-1}$	up to 10^{24} $m^{-2}s^{-1}$	> 10^{24} $m^{-2}s^{-1}$
Min angle of B to target	oblique	5 degrees	5 degrees
P target, parallel	10 MW/m^2	10 MW/m^2	40 MW/m^2
P target, perpendicular	10 MW/m^2	up to 10 MW/m^2	10 MW/m^2
Total ion fluence / plasma duration	10^{31} m^{-2}	10^{28} m^{-2}	10^{31} m^{-2}

- Nominal Performance Parameter (NPP) to be achieved after first operational campaigns
- Ultimate Performance Parameter (UPP) to be achieved after extensive operational period (~ 5 years)

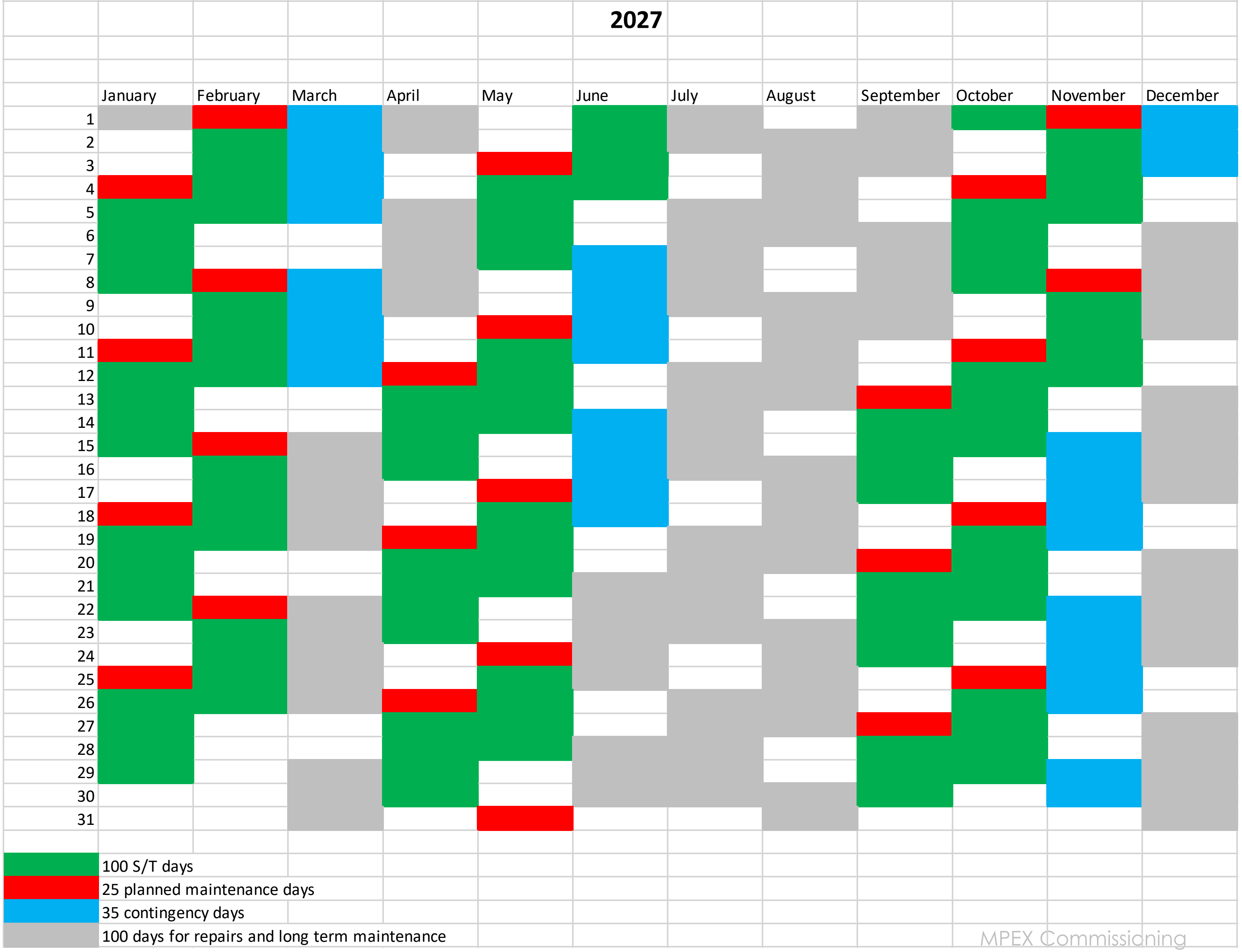
Annual operation targets

- 100 S/T days annual average [PR372-R]
- Possibility to operate 3 shifts for 12 days consecutive days [PR373-R]
- Scheduled maintenance 25% of operation time [PR374-R], hence 25 days annual average
- MPEX shall achieve 55% inherent availability (mean up time divided by mean up time and non-scheduled maintenance) [PR402-R], hence not more than 82 days non-scheduled maintenance annual average
- MPEX overall operational availability shall be more than 40% annual average [PR405-R]
- Scheduled long-term maintenance and upgrades, 8 weeks per year [PR406-I]
- Reliability of all MPEX systems of ONE occurrence per 10^6 seconds [PR418-R]

Notional draft schedule

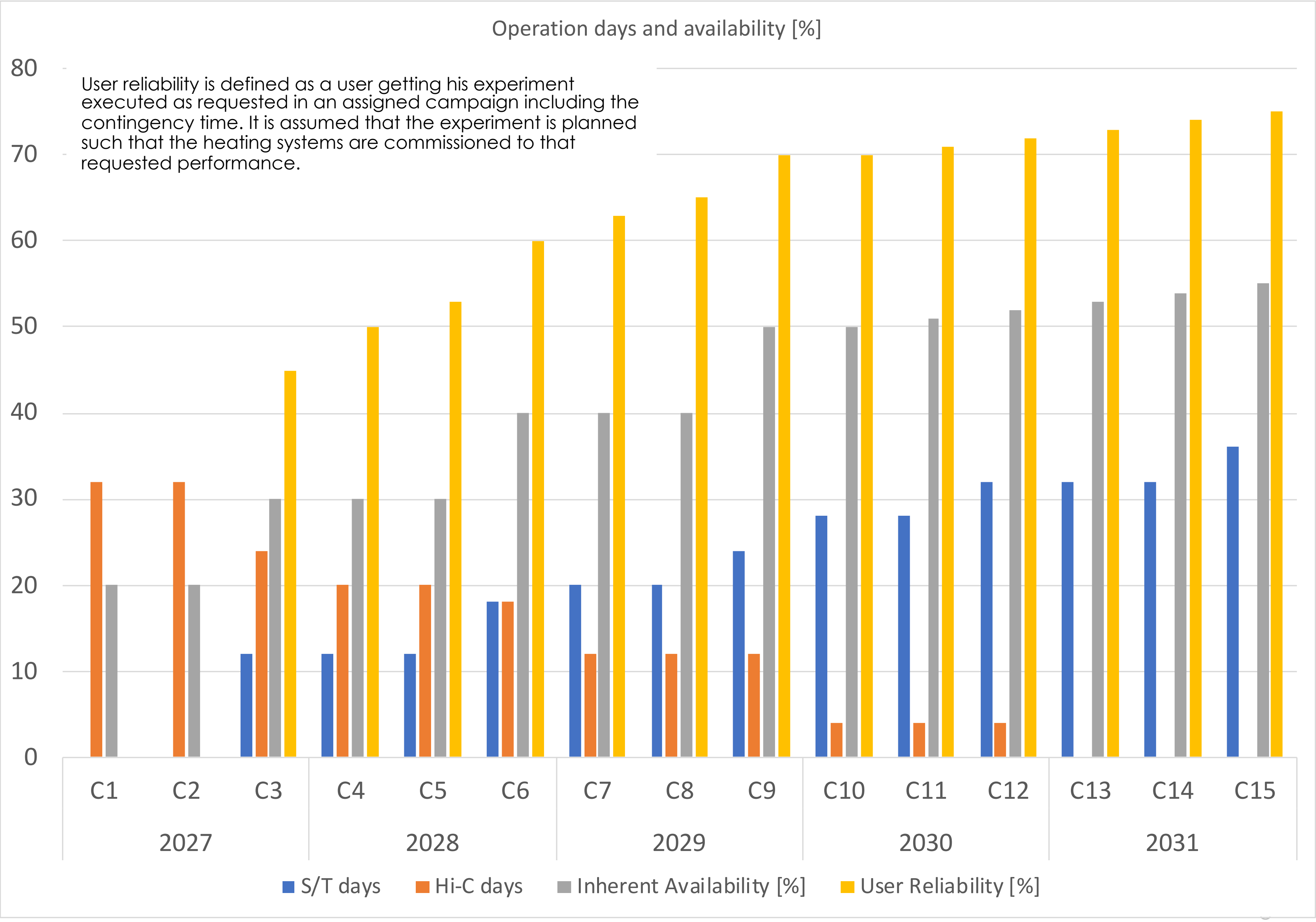
Notional generic schedule here shown for calendar year 2027 with three campaigns and one long summer shutdown:

- 100 planned days for science and technology.
- 25 planned (short term) maintenance days.
- 35 program contingency days to compensate for unplanned device failures.
- 100 days for repair and long-term maintenance. Please note that any long in-vessel maintenance work will be restricted to long summer shutdown.
- Restart of systems and commissioning is part of maintenance program time.



MPEX increase in capability/reliability/science operations

- MPEX high-level commissioning to full capability and availability over 5 years (similar to SNS).
- 15 campaigns over 5 years.
- Number of S/T days increase from 32 in first year to 100 after 5 years.
- Commissioning of systems after 5 years will be included in maintenance days.

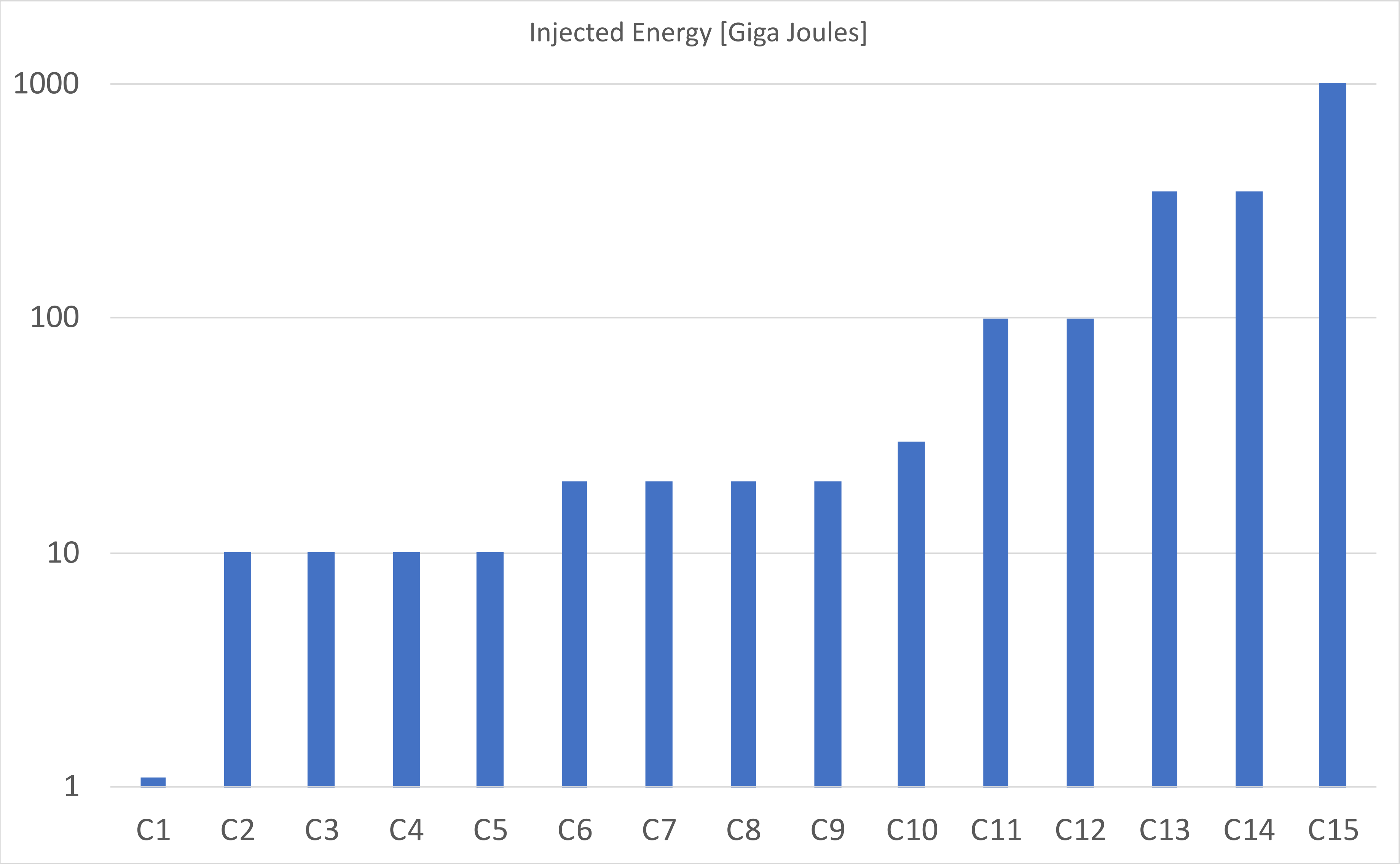


MPEX successively increases capability

- Increase in performance parameters and plasma duration vs time.
- The performance parameters are related to the plasma parameters T_e, T_i, n_e, Γ_i, $q_{//}$ in KPP, NPP and UPP (see slides before) only.
- Emphasis on pulse duration extension vs plasma performance increase is shown here as compromise but can be adjusted to the community needs.

	Performance	Duration	Fluence [m^{-2}]
C1	KPP	1 hr	10^{26}
C2	KPP	8 hrs	10^{27}
C3	NPP	10 sec	10^{27}
C4	NPP	1 min	10^{27}
C5	NPP	1 hr	10^{28}
C6	NPP	8 hrs	10^{28}
C7	UPP	10 sec	10^{29}
C8	UPP	1 min	10^{29}
C9	UPP	1 hr	10^{29}
C10	UPP	8 hrs	10^{29}
C11	UPP	36 hrs	10^{30}
C12	UPP	36 hrs	10^{30}
C13	UPP	4 days, 3 shift	10^{30}
C14	UPP	4 days, 3 shift	10^{30}
C15	UPP	Million seconds	10^{31}

MPEX increase in injected energy



Major operational risks

- Arcing may restrict injected power
  - Limitations: maximum target heat flux, T_e, T_i
- Density drop at high auxiliary heating
  - Limitations: maximum n_e, target ion flux, target ion fluence
- Target contamination due to impurities from helicon
  - Limitations: maximum ion fluence, restricted to high T_e scenarios, restricted to biased target operation, restricted to operation with seeded high-Z nobel gas impurities, restrictions in inclined target operation

Capability increase (tentatively)

- C1, C2 no science program
- C3: KPP performance with increasing pulse duration, NPP short pulse, second-generation helicon window, ITER pulse fluence
- C4: Inclined target operation, high recycling regime
- C5: NPP increasing pulse duration, PISCES-like fluence, wall conditioning methods applied
- C6: NPP increasing pulse duration, third-generation helicon window and second-generation ICH window – possibly reduced impurity production.
- C7: Full performance (UPP) in short pulses
- C8: Demonstration of all electron heating scenarios: EBW, Upper Hybrid, 2nd harmonic ECH and potentially Whistler
- C9: Demonstration of full operational domain in short pulses (whole reactor divertor plasma range)
- C10: Increase of pulse duration, He-cooled PFCs for high temperature PFC tests
- C11: Start of rad operation, Magnum-like fluence
- C12 – C15: Increase in pulse duration and fluence, reaching million sec pulses in C15.

MPEX Science exploitation evolution (example)

1. Short pulse high-Te regime (C3 to C4)
   i. Erosion/redeposition in high-T_e regimes with and without seeded impurities
   ii. Erosion/redeposition in high-T_e regimes, effect of magnetic pre-sheath
   iii. Effect of tilted angle of erosion of pre-manufactured surface morphology structures
2. Long pulse high-Te regime (C5)
   i. Heat flux testing of materials
   ii. Surface morphology changes in materials (fuzz etc.)
3. Long pulse, clean target and high-density operation (C6 onwards)
   i. Material testing, surface morphology changes, hydrogen retention in low fluence
4. Full performance, operational domain of reactor (C7 onwards)
   i. High power, shallow angle operation, melt-layer experiments, flux dependence on PMI, high heat flux tests
   ii. Test of first PFCs
5. Rad operation (C11 onwards)
6. High fluence operation (C12 onwards with milestone in C15)
   i. Influence of fluence on hydrogen retention
   ii. End-of-life tests of PFCs

Summary

- MPEX Science exploitation will be interleaved with high-level commissioning for about 4 years after end of project (CD-4).
- First year no PMI experiments to be expected.
- After 3 ½ years rad operation can start.
- High fluence reached and all mission need requirements fulfilled after 5 years.