What is behind Proton Therapy Facility Statistics?

PTCOG 46

Educational Workshop

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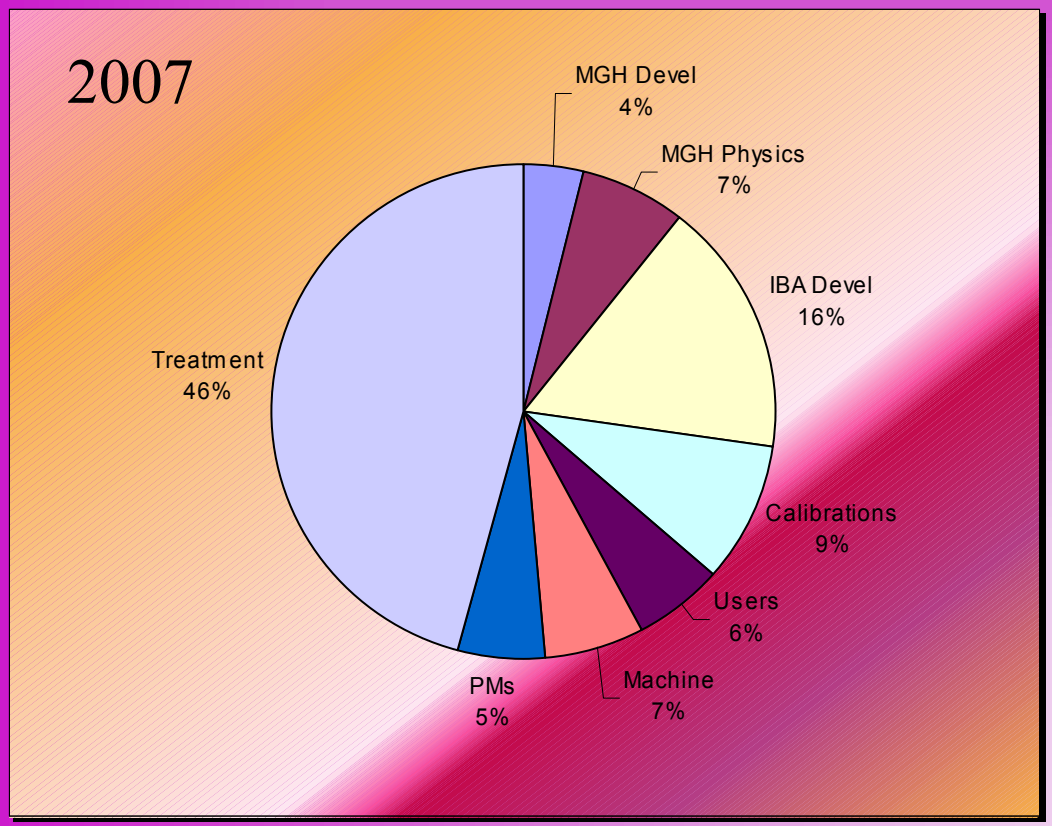
Thanks for input from:
MGH Team

What are the Questions?

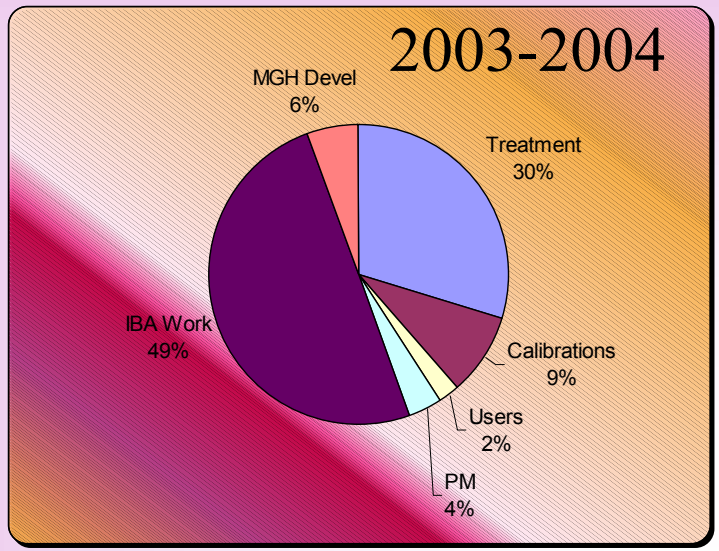
- What is the machine used for ?
- What data is needed ?
- What has to be done to ensure that the machine can be used for it's intended purpose ?
- Who can do what?
- What will determine who can do what?

How is (a / the) facility used ?



Of the time scheduled

- Treatment
- Medical Physics
- Developments
- Vendor
- Experiments
- Machine Work



What data is needed ?

- Treatment
  - Throughput, Reliability (Availability, Quality, …)
  - Happiness - *Subjective Ability to carry out desired Treatments*
- Medical Physics - Reproducibility, Predictability
- Developments - Ability to test/recover (availability)
- Vendor - Results
- Experiments - Results
- Machine Work (Maintenance, Repair) - Availability

Reliability

- Dictionary: "To have faith or confidence"
  - Dependable; Responsible; Trustworthy

- Medical Dictionary: "Yielding the same or compatible result in different clinical experiments or clinical trials"

Semiconductor Industry:

- *Reliability = (Quality %) * (Speed %) * (Uptime (Availability) %) (SEMI E10)*
- *Reliability = Probability that the equipment will perform its intended function, within stated conditions, for a specified period of time (SEMI E10)*

- How does it relate to Proton Therapy?

  Ability to do what one wants with the Equipment; whenever one wants to do it; and how one expected to be able to do it...

Reliability has to be measured via Specification/Stated Conditions through some measurable quantity (e.g. Quality, Speed, Uptime, Annoyance).

Availability =/= Reliability

Availability is a subset of Reliability

Reliability - Domain

If a tree falls in the forest, but nobody is there to hear it, does it make a sound?

or

Could what you don't know hurt you?

- If you lose a redundancy without knowing is that a lack of reliability? - YES
  - Implies always compare redundant measurements
- This underscores the importance of a Failure Modes Effects Analysis (FMEA)
  - The benefit of an FMEA in analyzing causal relationships is to:
    - Ensure that all important high level parameters are detected (e.g. beam parameters in Nozzle). So effects of all important devices are monitored downstream, at least.
    - Identify possible diagnostic locations to help identify low level issues
  - You have to choose if a parameter is important and what range of operational values that will be acceptable.
- This is something you CANNOT leave to come from someone's intuition!!

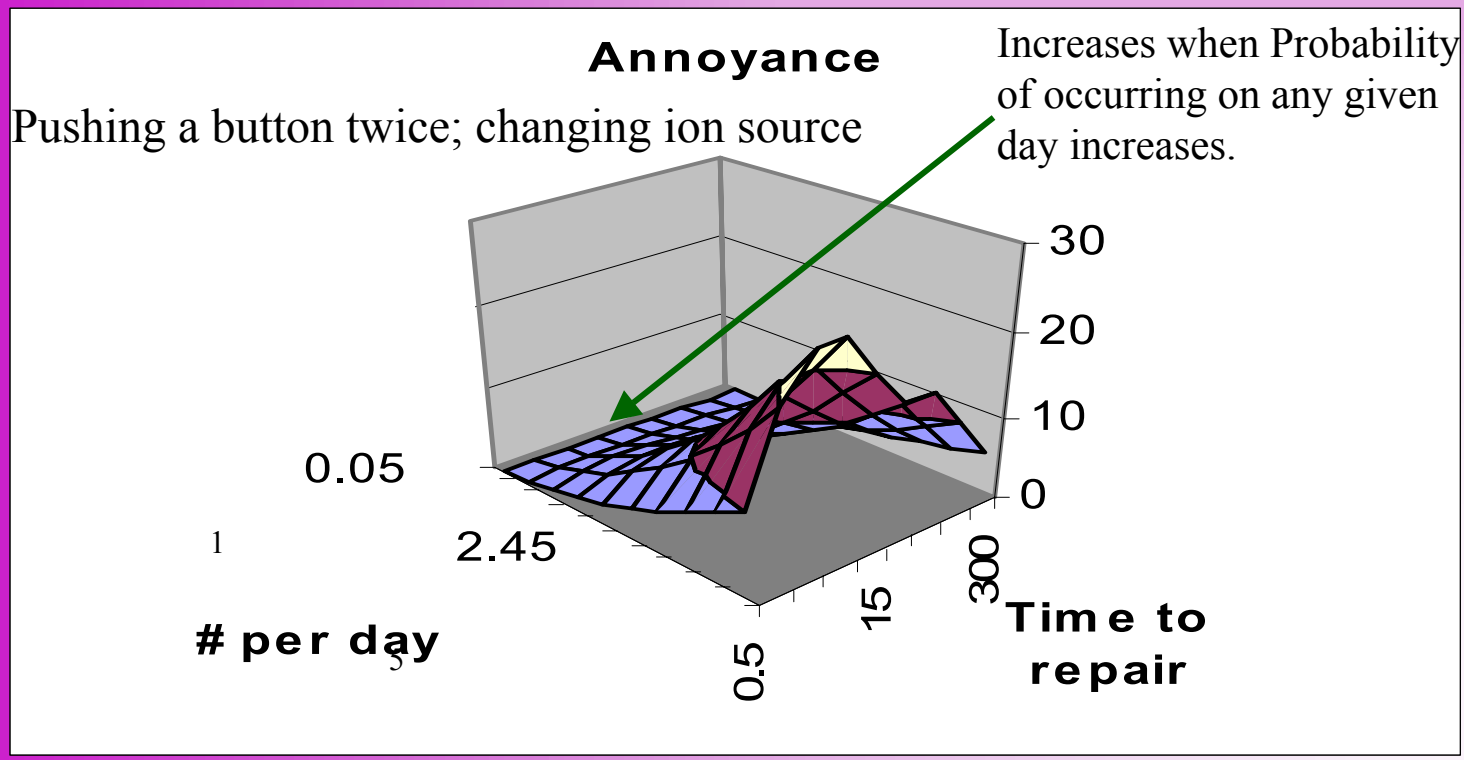
Reliability- When and How

1+1 + 10 + 3 (30 patients) =15 (9);

1+1+14+5 =21 (4) (more aggressive)

- When (Turn-on, QA, Tx, Cals, (Left))
- How: "Annoyance Factors" *(affects Speed * **Quality** + **Happiness**)*
  - # of problems (or complaints) per day
  - # of recurring problems per week / month
  - time to recover from problems

E.g.: Pushing a button twice; changing ion source



Availability

$$\text{Availability} = 1 - \left[\frac{\text{Unscheduled Downtime during Tx}}{\text{Scheduled Tx Time}}\right]$$

94% = 99% * 99% * 99% * 99% * 99% * 99%

Sys1 * Sys2 * Sys3 * Sys4 *Sys5 * Sys6 (dependent)

Not all problems are created equal!

Problems Common to all treatment rooms are obviously more critical, especially if there are redundant systems such as multiple (interchangeable) Gantry Rooms.

System Availability = Common * [(TR1 + TR2 +… TRn)/n]

(TR1 and TR2 are INDEPENDENT)

e.g.

50% = 100% * [(100% + 0 %)/2]

50% = 50% * [(100% + 100%)/2]

During Tx or over 24 hr period?

Treatment Numbers:

- Patients/Day = Hours/Day*Fractions/Hour
- Patients/Year ≈ $\frac{\text{Days/Year} * \text{Patients/Day}}{\text{Fractions/Patient}}$
- e.g.
  - Large Field Gantry Treatments
    - 15 min/Frac, 8 hrs/day ==> 32 patients/day; 272 patients/year (30 Frac)
    - 30 min/Frac, 8 hrs/day ==> 16 patients/day; 136 patients/year (30 Frac)
  - Ocular Treatments (5 fractions)
    - 5 patients/day ==> 255 patients/year
  - Radiosurgery Treatments (1 fraction)
    - 1 patient/day ==> 255 patients/year

30 min vs. 15 min

16 hrs vs. 8 hrs

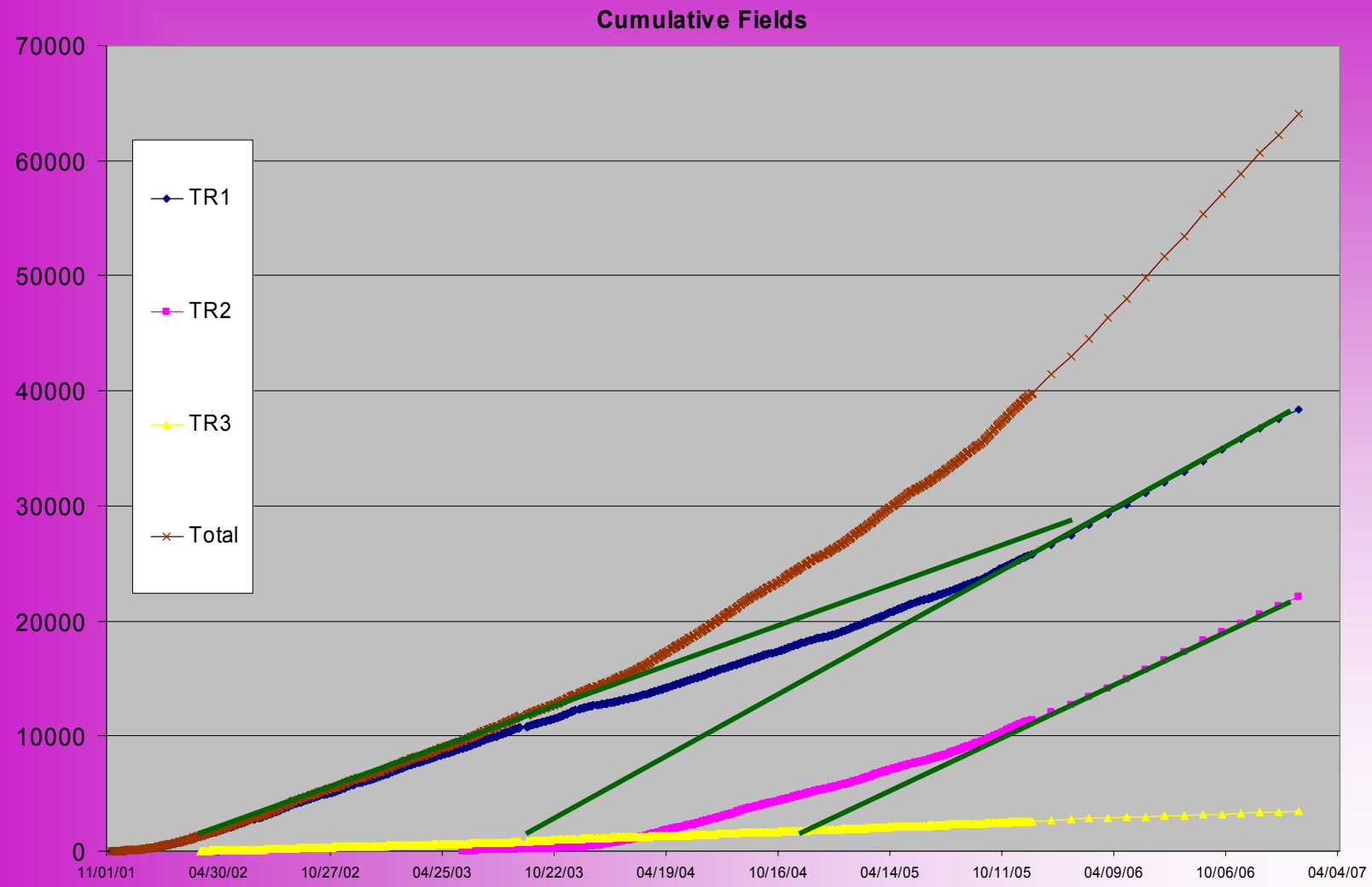
Difference Machines!!

- So with 20min/patient (10 hrs), 2 Gantry rooms, 1 ocular, 1 Steriotactic:
  - 30*2+5+5=**70** patients/day ==> 18,200 fractions/ year ~ 2080 patients/year *(All)*
  - or **65** patients/day ==> 16,900 fractions/ year ~ 780 patients/year *(No Stereo)*

0.93 vs. 0.375

Be careful which numbers you see - how do you determine the 'real work'/ machine data?

The Real Work - # of Fields



How to ensure Reliability
Start at the beginning?

- Design
  - Appropriate Specifications
  - Realistic Goals
    - Perfect Operation?
    - 8 hour, 16 hour, 24 hour Operation?

- *Is is a legitimate application of the '95%' availability specification if a system needs fixing during the Treatment day regularly, but this does not use up the 5% limit?*
- *Is it a legitimate application of the '95%' availability if the system is 'worked-on' or repaired after the Tx day, and this work is NOT included in the availability?*

- Implementation
  - Use the correct parts, wires, connectors, motors, encoders..
  - Define methods to meet reliability goals
- Testing; UT, IT, ST
- Diagnostics and Automation
- AND…
- BUT …

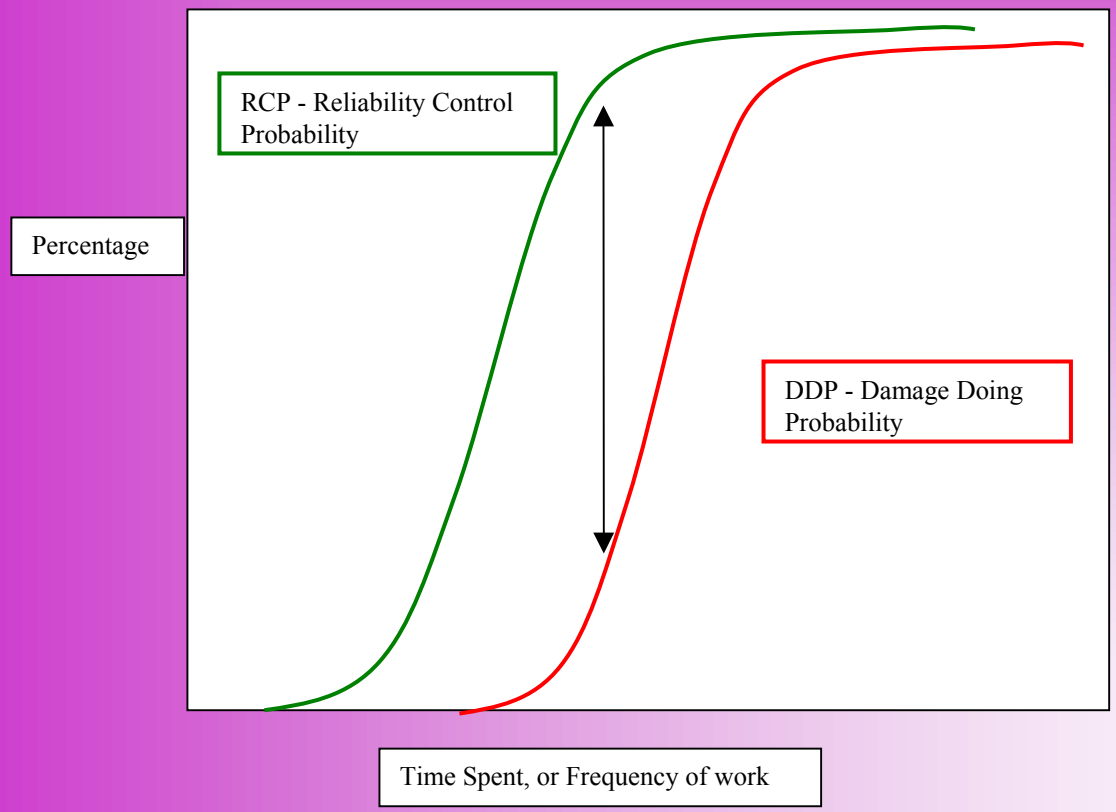
How to ensure good Availability assuming NON-PERFECT Reliability?

- **Diagnostics**
  - Human Diagnostics
    - Reduce Time
  - Self Diagnostics - AUTOMATION
    - Self Correcting
    - Redundancy (2 out of 3 instead of 2 out of 2 redundancy)
- Maintenance
  - Appropriate **Preventive Maintenance?**
  - Easy 'Curative' Maintenance
  - Note that Maintenance level requirements ARE DESIGNED!
  - Spare Parts Management / Quality
- **Re-Design** or Retrofit!
  - What can be WRONG in a design that would reduce availability?
  - Do an !! FMEA !!
  - Reduce Time for Repairs - Re-Design for Maintenance
  - Quick Diagnoses of problems - Re-Design for Diagnostics

Whose responsibility is this and what is their motivation?

… AND Reliability Through Preventive Maintenance

is a probability subject



Who should/can do What?

- Define Terms
  - Who/What is the Customer ?
  - Who/What is the Manufacturer ?
  - Who/What is the Maintainer ?
  - Level of Difficulty of Work after 'Acceptance' depends upon:
    - Design
    - Implementation
    - Automation
    - Diagnostics
    - Parts Management
- Treatment Type/Process
  - Should be controlled by Customer
  - But in some cases it might be done with Help by Vendor
- QA
  - Should be controlled by Customer
  - But in some cases it might be done by a certain kind of Vendor

- Where does the Competence Reside?
- What is Level of Difficulty?
- Training? Money?

W h o c a n / s h o u l d d o W h a t ?

Level of Difficulty

Task	Simple / Automated	Medium Hard	Hard	Proprietary
QA	Cust	Cust	Cust/Vend	??
Tx	Cust	Cust	Cust	N/a
Ops	Cust	Cust + Vend Hlp	Cust + Vendor	Vendor
PM	Cust	Cust + Vend Hlp	Vendor	Vendor
CM	Cust	Cust + Vend Hlp	Vendor	Vendor
Parts	Cust	Vendor	Vendor	Vendor

Warnings/Conclusions:

- *Measure Statistics against a specific spec !*
- *Measure an observable - direct or indirect !*
- *Consider development time !*
- *Consider time frame is the Availability Spec?*
- *Consider cost of ensuring higher reliability at the outset - whose responsibility is it? (Motivation?)*
- *Clinical QA and Machine Design !*
- *Using the "Production Machine" or the "Prototype"*

End Slides

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Facility Statistics

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