Capacity Optimization Planning System (CAPS)

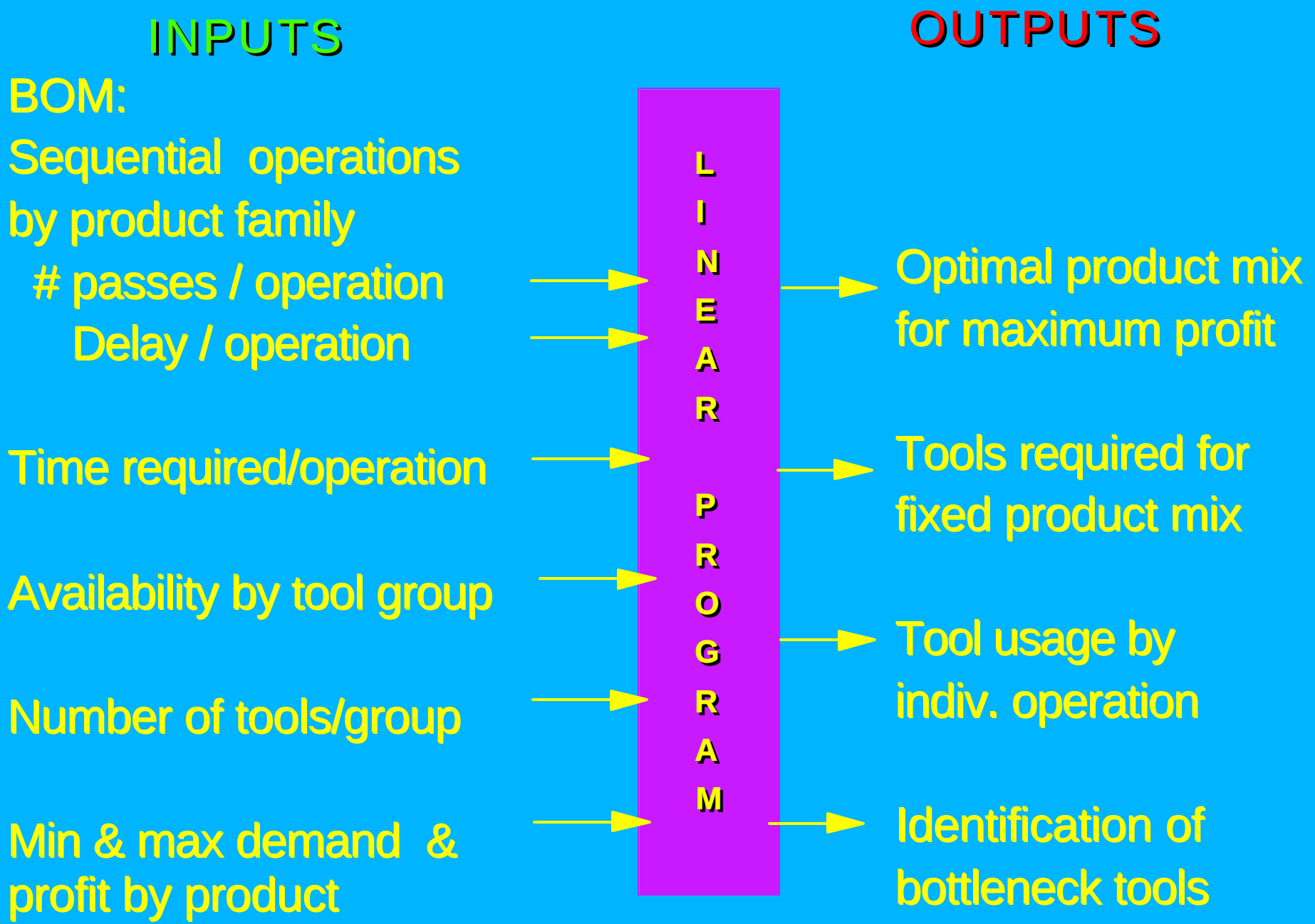
Stuart Bermon
Sarah Jean Hood

IBM T. J. Watson Research Center

IBM's Capacity Optimization Planning System (CAPS) for Semiconductor Manufacturing

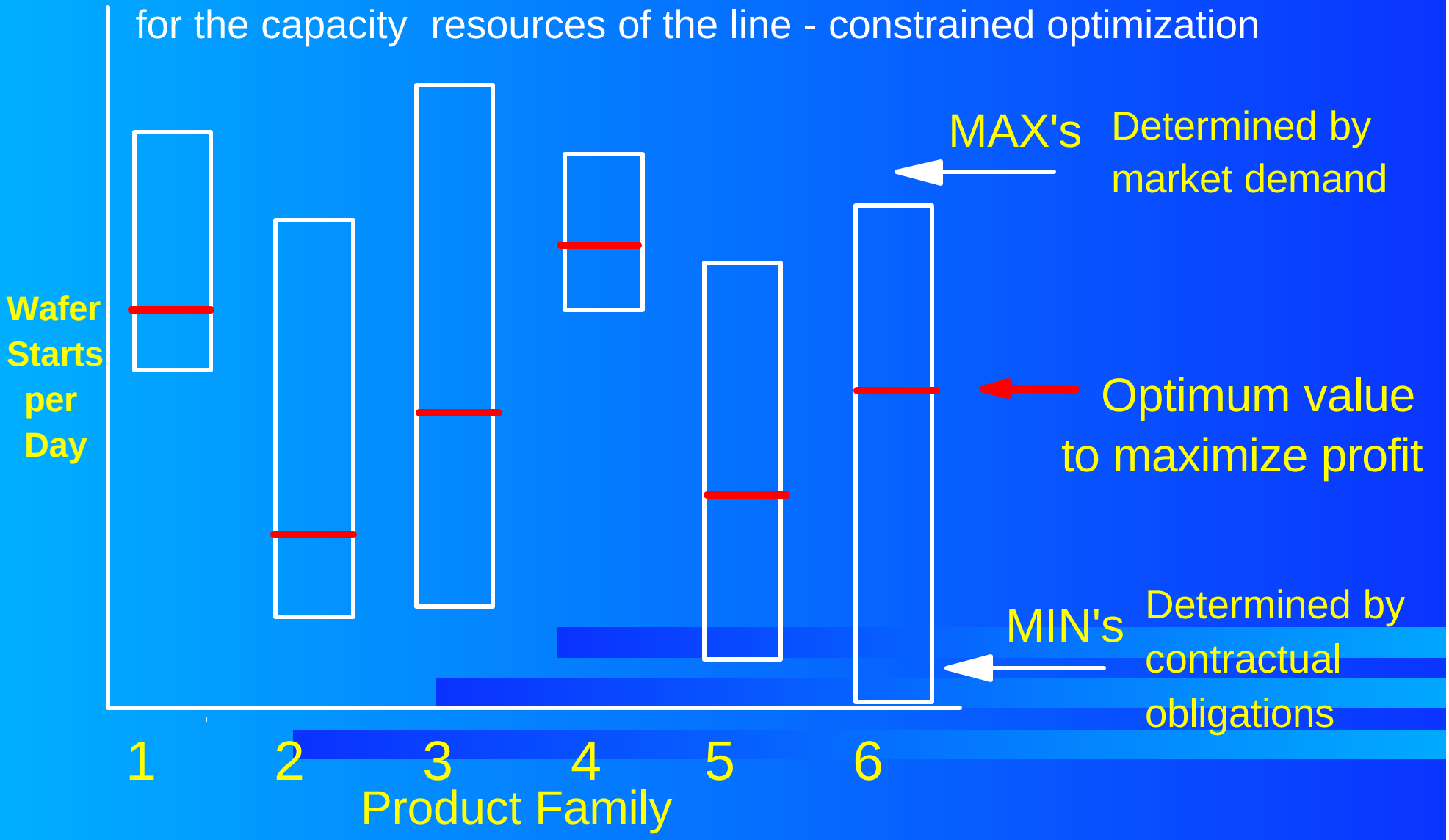
- CAPS is a decision-support system based on linear programming using OSL for strategic and tactical planning of manufacturing capacity.
- CAPS finds the volume mix of products to maximize profit, constrained by the exisiting tool capacity, or identifies the tool capacity required to manufacture a speciifed mix of products.
- The formulation must deal with parallel, unrelated tool groups (cascade tools) that may perform the same operation at different rates, capture the preferential (cascade) order in which to use such tool groups, and be able to identify the true bottleneck tool groups.
- Planners use CAPS to reconcile demand forcasts with manufacturing capacity and to generate requests for capital investments.
- IBM Burlington management credits CAPS with identifying tens of millions of dollars in addtional revenue opportunites and avoiding significant unnecessary capital expenitures.

Capacity Optimization Planning System

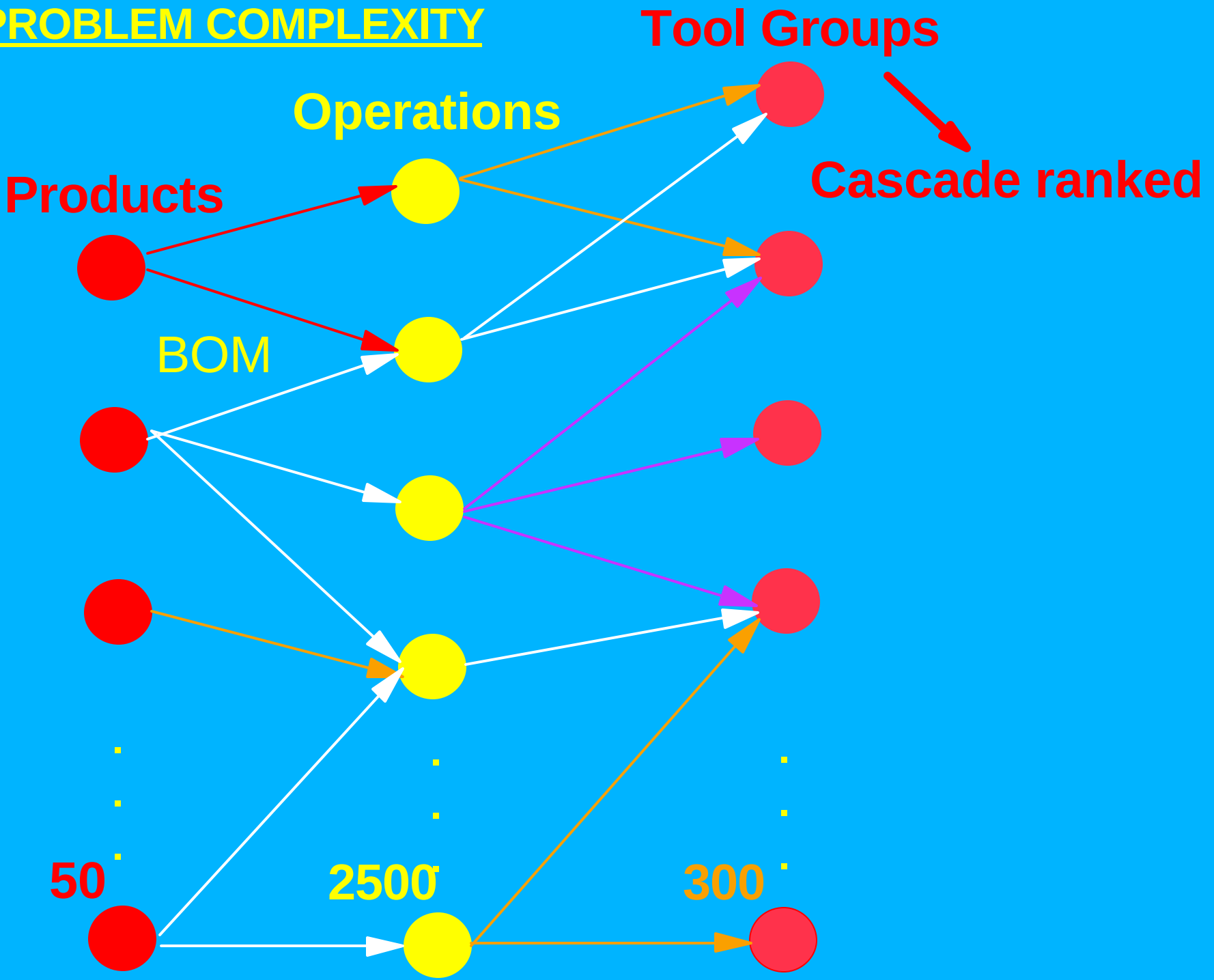


CAPS uses Linear Programming to maximize overall profit when product volumes can vary between lower and upper bounds

Each product family, characterized by its own unique routing, competes for the capacity resources of the line - constrained optimization



THE PROBLEM COMPLEXITY



An equation for each operation s: Left side is total parts coming to s summed over all products. Right side shows how those parts are allocated to tool groups capable of performing operation s.

Decision variable for product start volumes

Passes per day for product p thru op s BOM(p,s)

$$\sum_{p \in P} w_p J_{p,s} = \sum_{t \in \tau(s)} f_{s,t} \frac{N_t A_t}{H_{s,t}}$$

Availability

$\forall\ s \in S$

Parts per day t can make

Processing time for op s on tool t

Product-start/tool-allocation decision variable for fraction of tool group *t's* capacity spent performing operation s

Provides output for number of passes per day and tool usage by operation desired by engineers in charge of individual tool groups

The CAPS LP objective function

Maximize:

Soft constraints

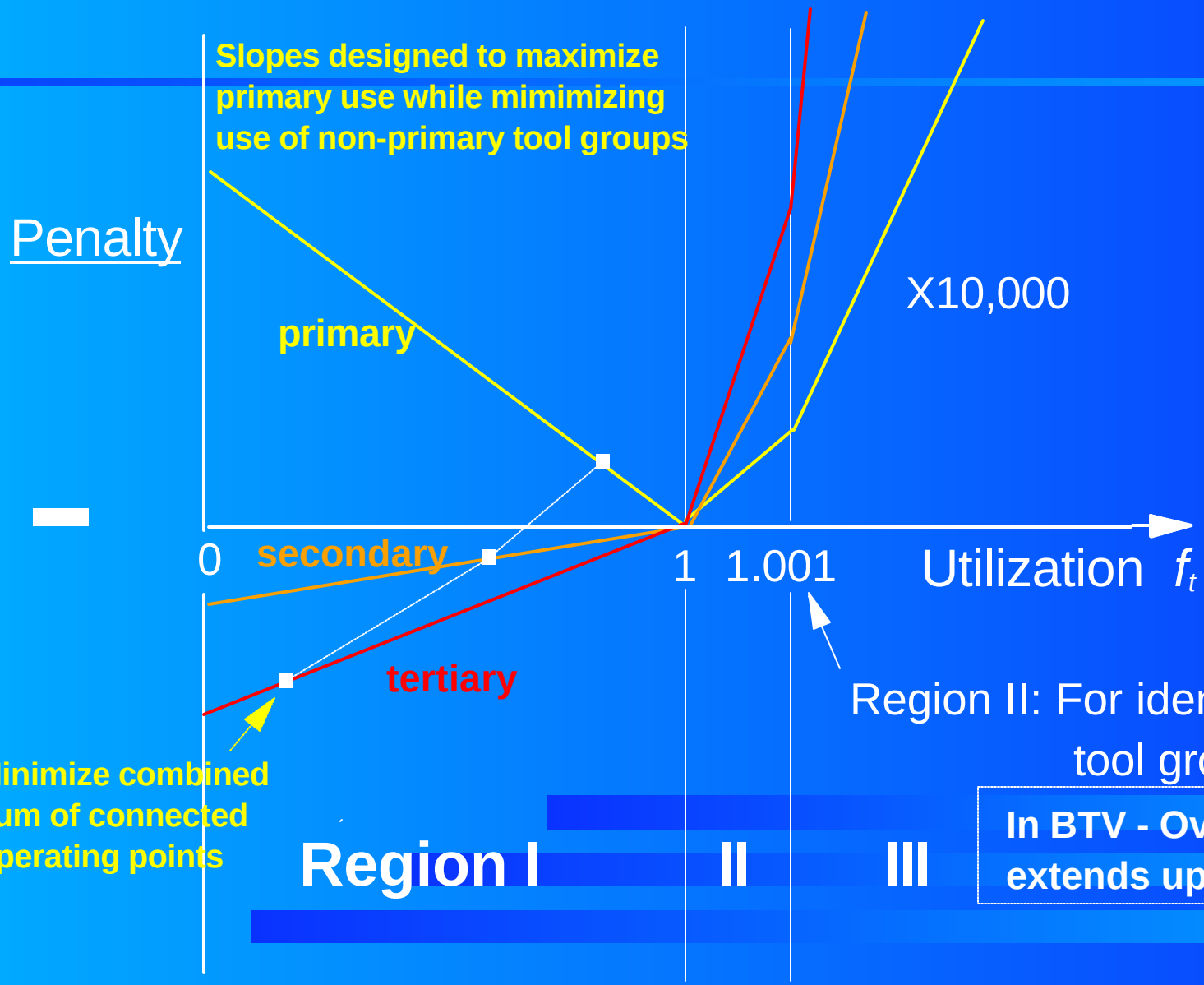
Total profit summed over all products

–

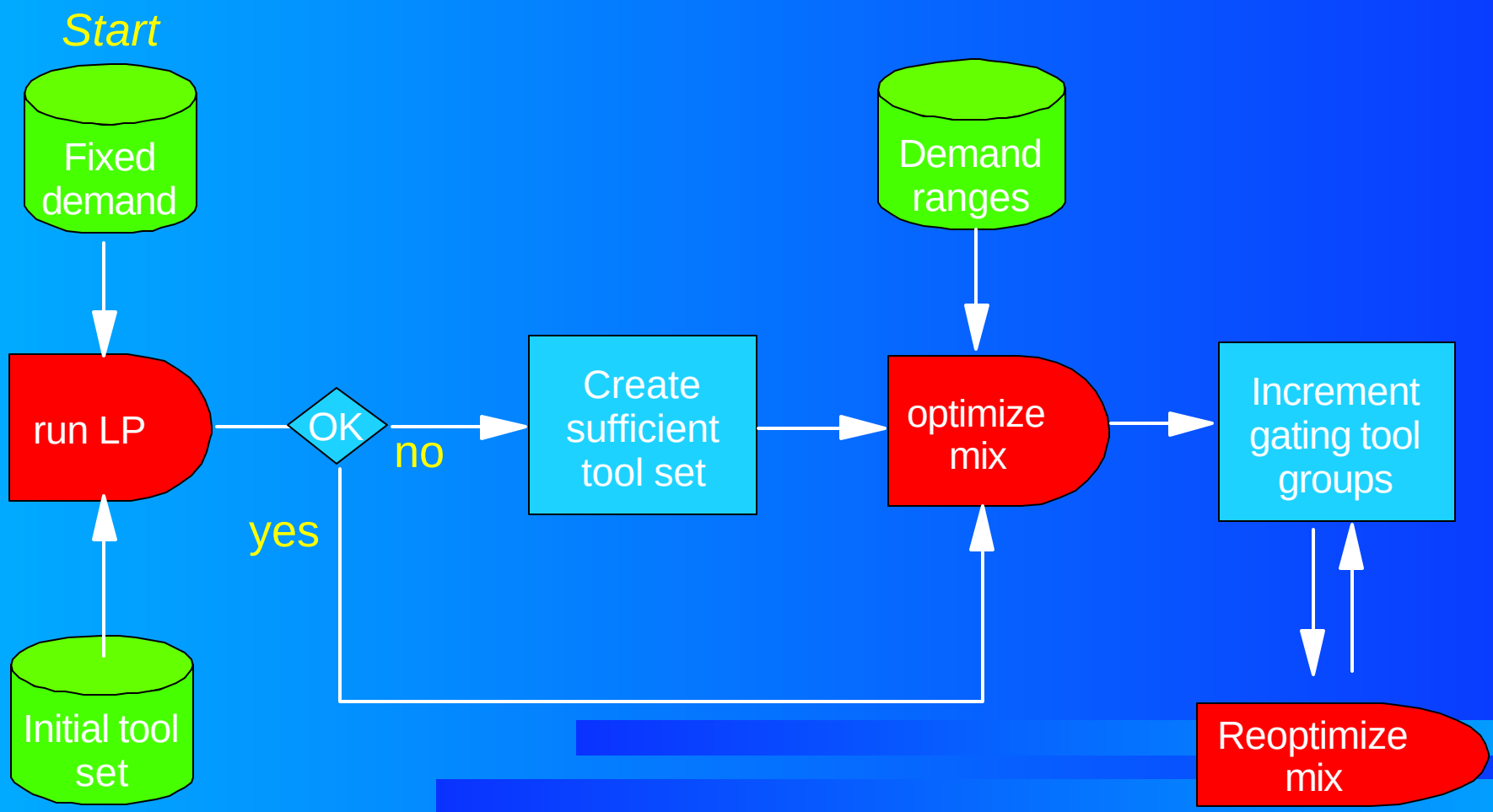
Penalty functions $\mathbf{H_i(f_t)}$ control overuse of tool groups and allocate work in preferred rank order

Provides data on insufficient tool groups rather than simply returning an infeasible solution.

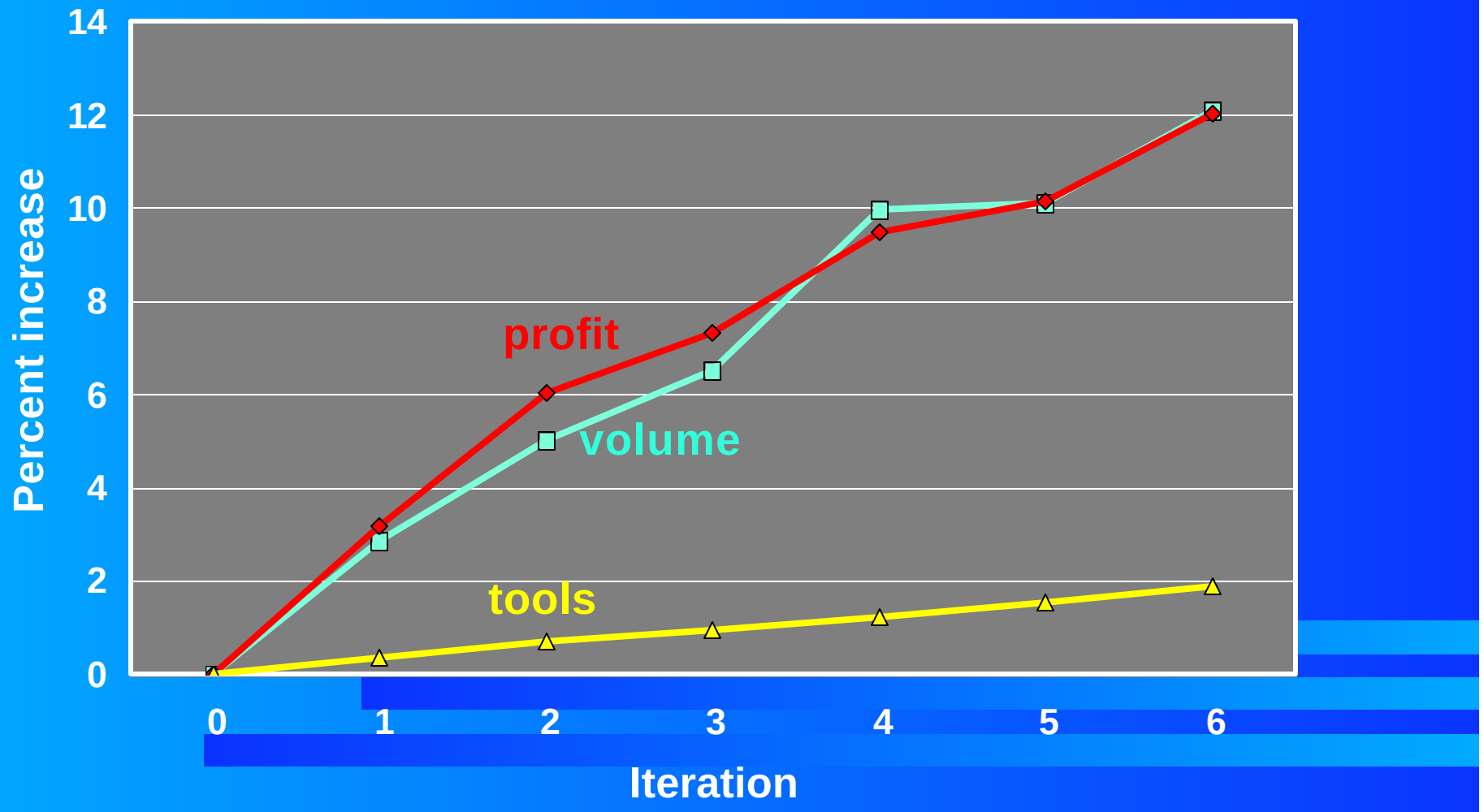
Piecewise linear penalty functions for controlling overuse and allocating work in sequence to a ranked cascade of three tool groups - 3 regions of interest



An example of CAPS Use: **Start with fixed demand; determine sufficient tool set; expand product ranges; find new best mix within ranges; increment bottleneck tools for max increase in production.**



Incrementing capacity by adding to gating tool groups to increase volume & profit



Delay Time Offset CAPS (DT CAPS)
Offsets tool loading by delay in the line

Cycle times in sc mfg vary between 50 and 150 days. Starts input in one period may undergo processing on an operation several periods later. Flow is re-entrant. Competition for capacity between WIP and new starts is important.

Each sequential operation ss performed in period i on product p has a characteristic delay time D(p,ss,i) which offset the starts.

Loading for an operation ss in period 7 with a delay of 4.30 periods is a combination of wafer starts in periods 2 (f =0.3) and 3 (f =0.7)

Distinct operation - Sum wafer starts over a distribution of periods

Manager of site operations at IBM Micro-electronics Division Burlington says CAPS:

`

- Being used for over 90% of capacity analysis sizings. Product mix scenarios can be analysed in hours versus days.
- Used to determine process tooling requirements for MD's recently approved capital investment project (100's of millions of dollars).
- Enables a quick fill of scenarios to maximum capacity resulting in the indentification of addtional revenue opportunites worth tens of millions of dollars per year.
- Provides rapid impact analysis of the feasibility of site technology conversions, such as from Al to Cu metal interconnect technology.
- Allows better understanding of the inherent flexability of the existing capacity base and the requirements for constructing new factories.
- Provides fast, accurate analysis & comprehensive reports