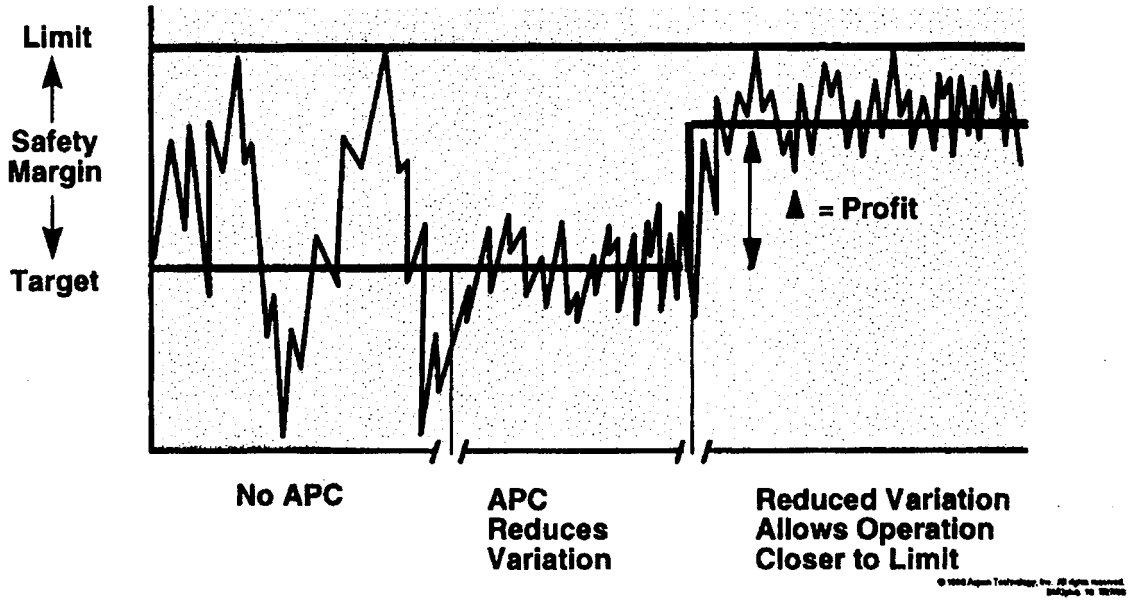
1.4 INDUSTRIAL USE OF MPC: OVERVIEW

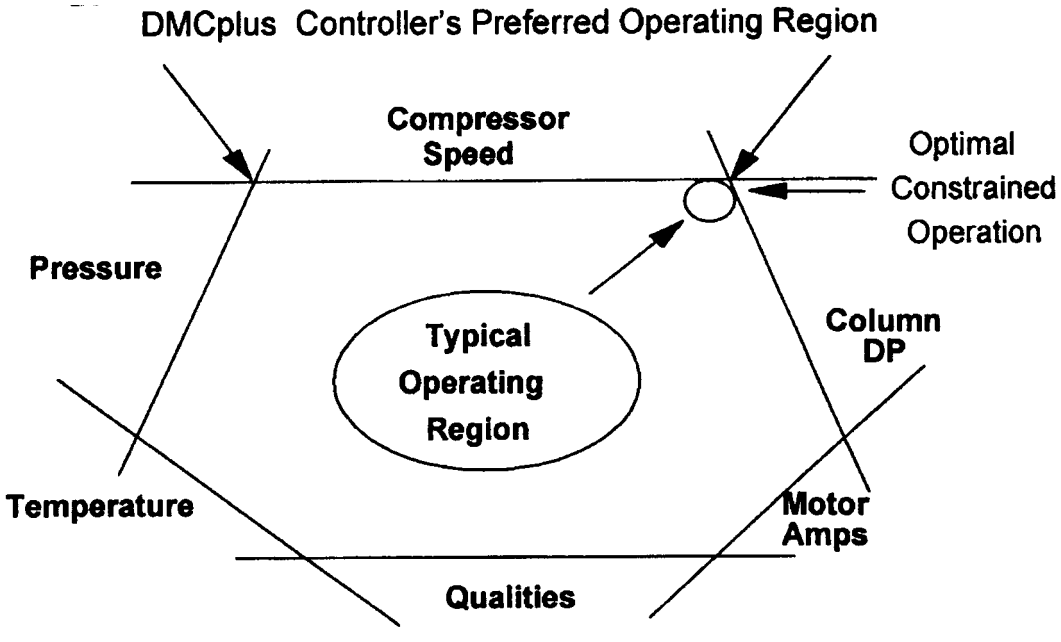
1.4.1 MOTIVATION

Profitability potential with multivariable control

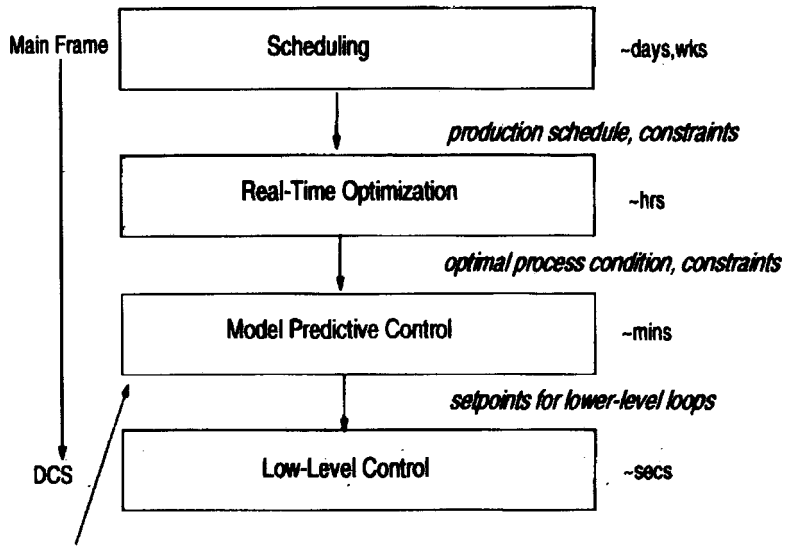
- reduce variability of key variables by 50 % or more.
- increase yield of more valuable products,



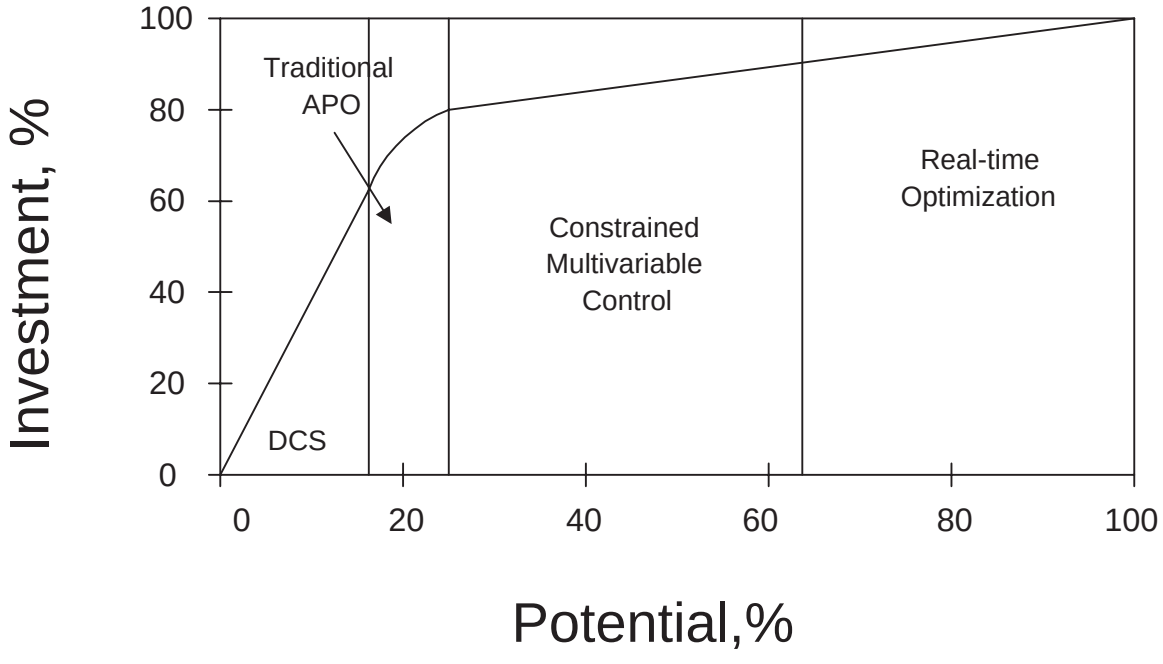
Benefits of control and optimization



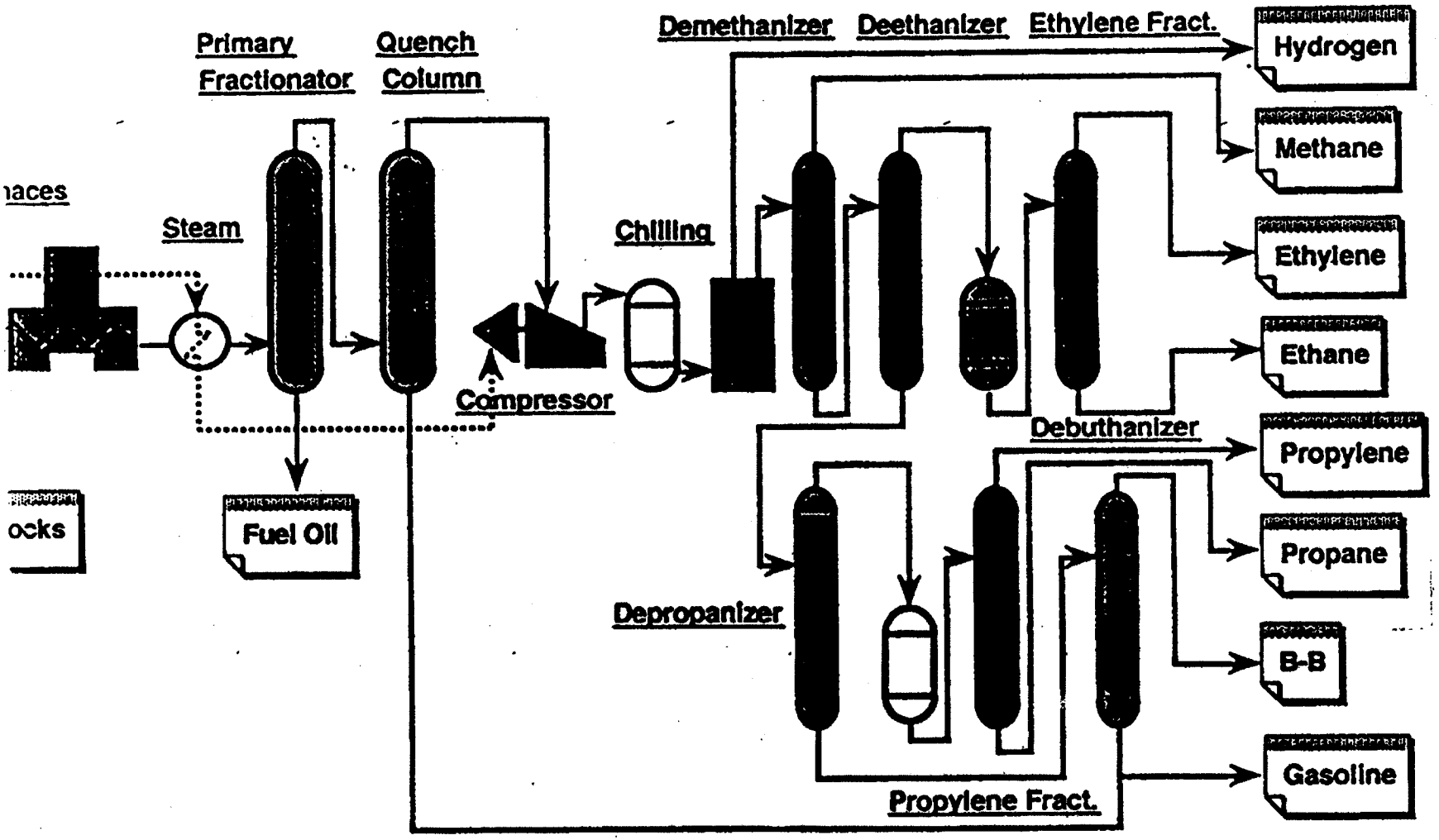
MPC within plant automation hierarchy



Move the plant to the current optimal condition fast and smoothly w/o violating constraints


Investment, %
100
80
60
40
20
0
Traditional
APO
DCS
Constrained
Multivariable
Control
Real-time
Optimization
0
20
40
60
80
100
Potential,%

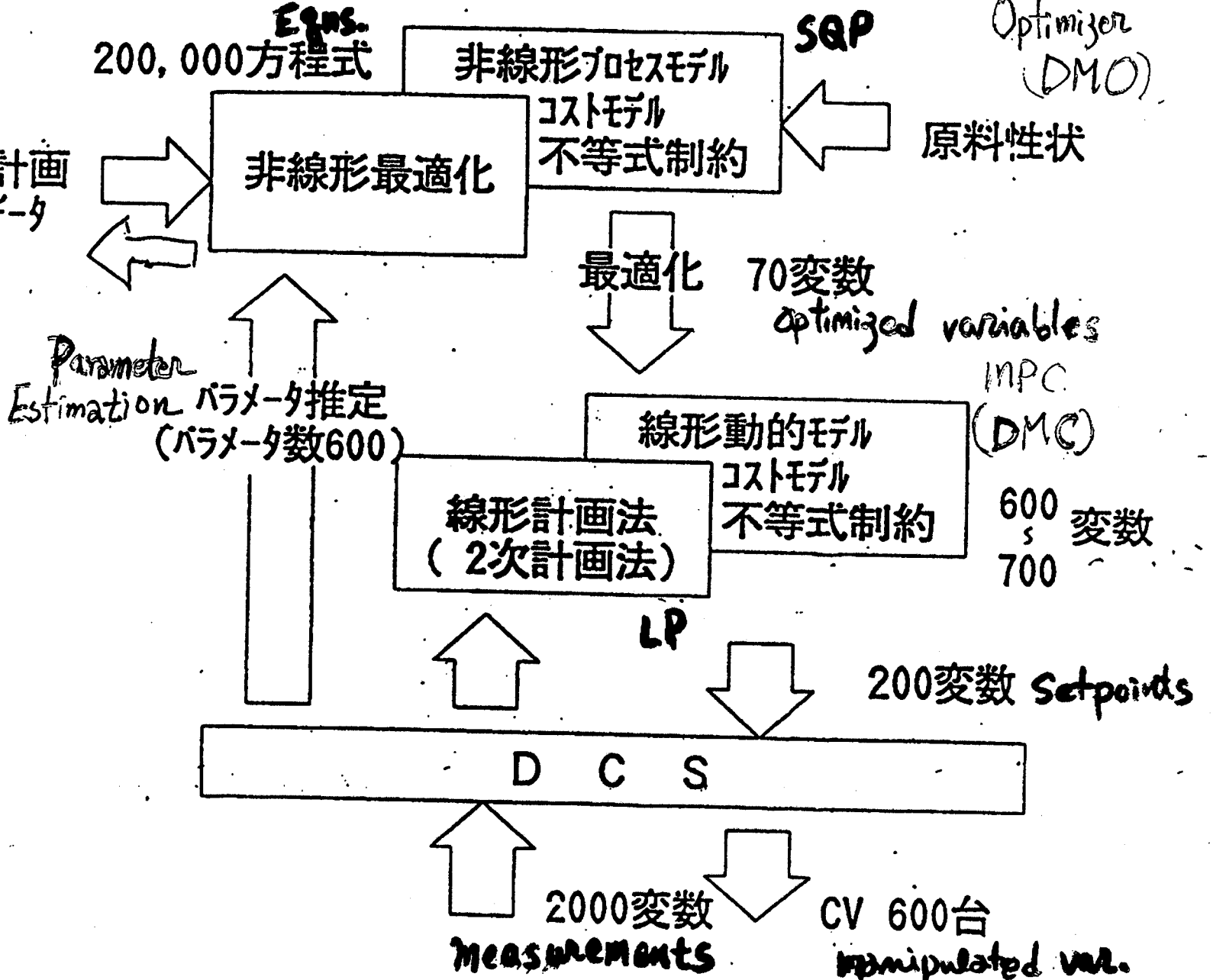
Block Diagram of Olefins Plant



Ethylene Plant

DEC/ALPHA

プロセスオリエンティッドな制御システム例



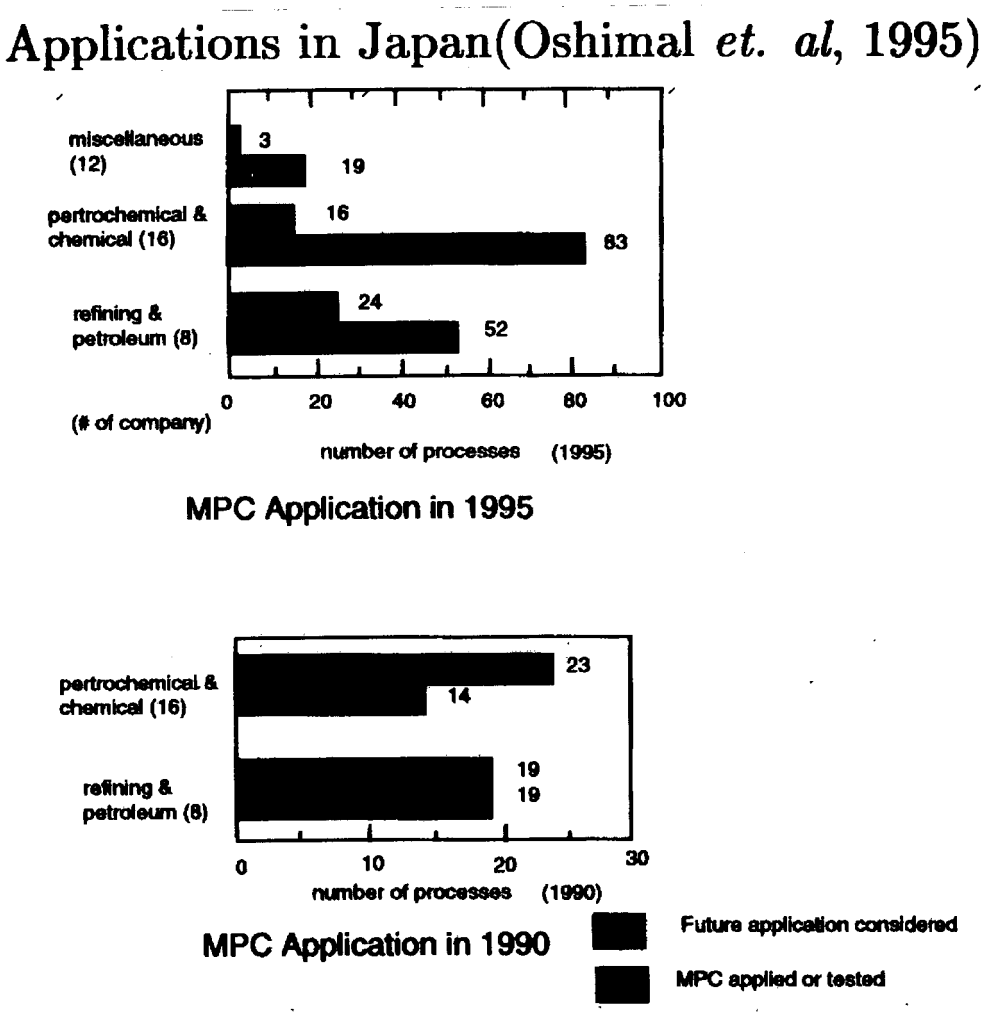
1.4.2 SURVEY OF MPC USE

Current status of MPC application(North America/Europe)

Applications by five major MPC vendors (Badgewell, 1996)

Area	DMC Coop.	Setpoint Inc.	Honeywell Profimatics	Adersa	Treiber Controls	Total
Refining	360	320	290	280	250	1500
Petrochemicals	210	40	40	-	-	290
Chemicals	10	20	10	3	150	193
Pulp and Paper	10	-	30	-	5	45
Gas	-	-	5	-	-	5
Utility	-	-	2	-	-	2
Air Separation	-	-	-	-	5	5
Mining/Metallurgy	-	2	-	7	6	15
Food Processing	-	-	-	41	-	41
Furnaces	-	-	-	42	-	42
Aerospace/Defence	-	-	-	13	-	13
Automotive	-	-	-	7	-	7
Other	10	20	-	45	-	75
Total	600	402	377	438	416	2233
First App	DMC:1985	IDCOM-M:1987 SMCA:1993	PCT:1984 RMPCT:1991	IDCOM:1973 HIECON:1986	OPC:1987	
Largest App	603×283	35×28	28 ×20	-	24×19	

Current status of MPC application(Japan):



1.5 HISTORICAL PERSPECTIVE

- The idea of using a model for prediction and optimal control computation has been around for long time.

Note that research on optimal control was most vigorous in the 50s and 60s. Most of the results during this period were for open-loop optimal control. For feedback implementation, they hinted the idea of *receding horizon control*. However, most of the results were impractical due to the lack of implementation hardware.

Some remarkable results of this period include

- Pontryagin's maximum principle.
- Hamilton-Jacobi-Bellman equation for optimal feedback control.
- Feldbaum's dual control concept.

- Due to the lack of sophisticated hardware, it was highly desirable to derive a closed-form control law that could be implemented with computational equipments available at reasonable costs. The work of Kalman represents a major achievement in this regard.

  Kalman derived analytical solutions to

  - linear quadratic optimal control problem for deterministic systems $\Rightarrow$ (∞-horizon) LQR
  - the same problem for Gaussian stochastic systems $\Rightarrow$ LQG = LQR + Kalman filter

  These solutions were important because they represented very few *analytial* solutions to optimal feedback control problems.

  However his work (based on the idea of stage-wise solution using dynamic programming) could not be extended to constrained systems or nonlinear systems.

- In the 70's, Kwon and Pearson discussed the idea of *receding horizon control* (a cornerstone of MPC) in the context of LQ optimal control and how to achieve stability with such a control law.

  However, they did not consider constrained / nonlinear problems and failed to motivate the need for such an approximation.

- In the late 70s and early 80s, there were several reports of successful use of optimal control concepts in oil industries. For instance, Charlie Cutler reported the success of implementing the so-called Dynamic Matrix Control in Shell Oil refining units.

  This started an avalanch of similar algorithms and industrial projects. From here on, process control would never be the same.

- The industrial success renewed the academics' enthusiasm for optimal control. Prototypical algorithms were analyzed and improved. Also, connections to the Kalman's work and other optimal control theories were brought forth.

- Now, MPC is an essential tool-of-trade for process control engineers. There are more than a dozen vendors offering commercial software packages and engineering services. There is probably not a single major oil industry where MPC is not employed in its new instaillations or revamps. MPC is also very well understood from a theoretical standpoint.

1.6 CHALLENGES

1.6.1 MODELING & IDENTIFICATION