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THE MIDDECK ACTIVE CONTROL EXPERIMENT (MACE):

IDENTIFICATION FOR ROBUST CONTROL

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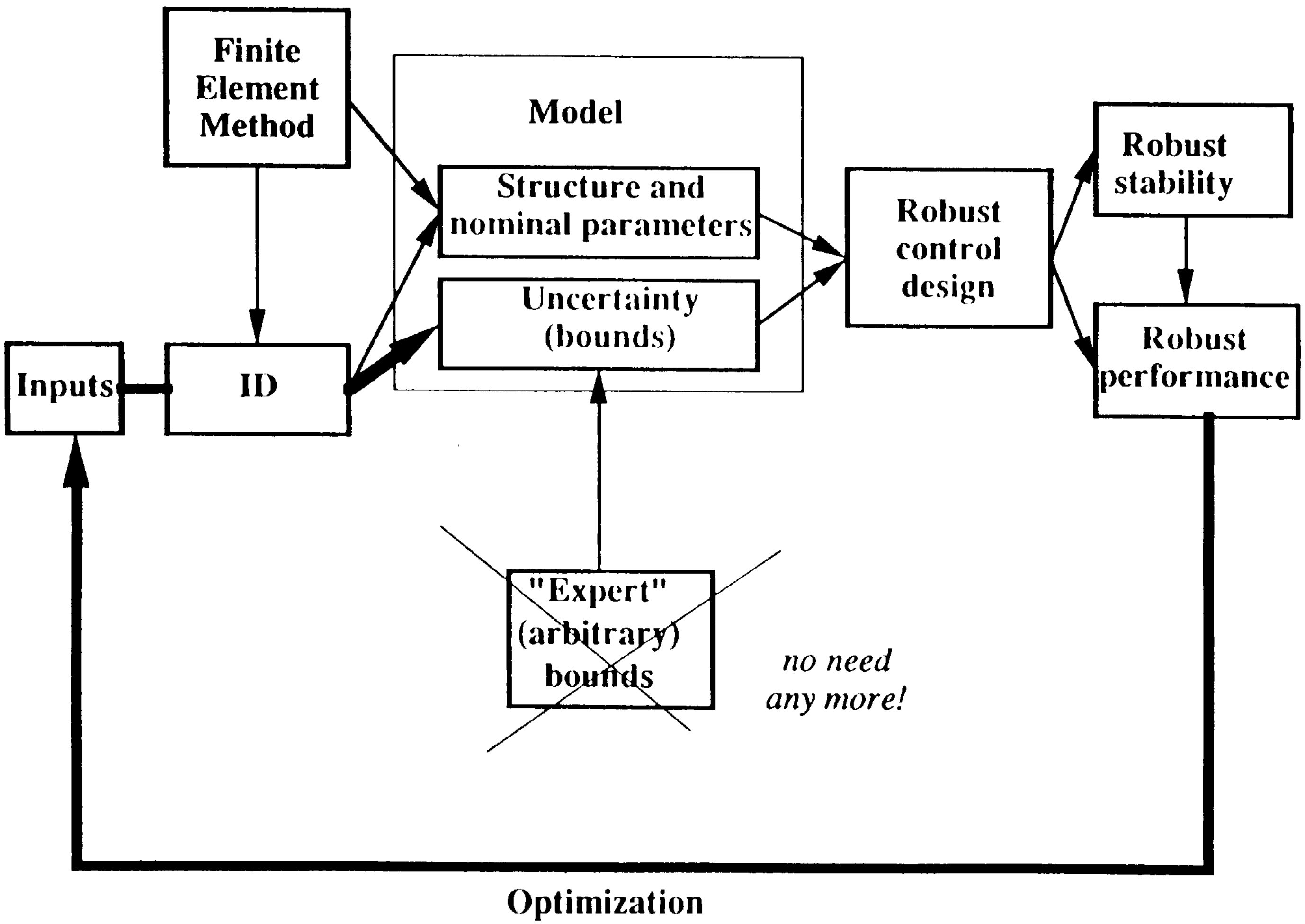
Identification For Robust Control

Stages of Design



Three Levels of Identification

	1	2	3
Algorithm	• Empirical Transfer Function Estimate • Eigen Value Analysis •	• Least Square • Maximum Likelihood • Prediction Error • ....Methods	• **Extended Kalman-type filters (state and parameter estimation)**
Model	• SISO • MIMO (deterministic)	• TF • ARMAX $A(q)y(t)=B(q)u(t) + e(t)$ $t = 0,\ldots,K$	• **State-space** $\dot{x} = A(\alpha)x + B(\beta)u + \xi$ $y = C(\beta)x + D(\beta)u + \eta, \quad t \in (0,T)$
Product	• Model structure (number of modes, preliminary estimates)	• Fitted estimates [but of "indirect" parameters $\gamma = \varphi(\alpha,\beta)$]	• **High-precision estimates of "direct" parameters:** **- α (frequencies, damping ratios)** **- β (mode shapes, masses)** • **Realistic bounds**

Basic Elements of The Approach

1. Non-linear problem of Riccati equation control for augmented covariance matrix:

$$\left[\begin{array}{c:c} P_x & P_{x\alpha} \\ \hdashline P_{\alpha x} & P_\alpha \end{array}\right]$$

2. Equivalent linear problem
   (Received on the basis of non-traditional usage of RE analitical properties)
3. Converge numerical algorithm of optimization
4. Extended Kalman filter
   (Solution on the basis of decomposition with respect to frequencies)
5. Robust control problem
   - Cost averaging techniques (use the "Post-ID" bounds directly)
   - Petersen -Hollot's bounds (need modification)

a). $SA_0 + A_0^T S + (K + \beta\gamma N \mathbf{W} N^T) - S(BR^{-1}B^T - \beta\gamma^{-1} L \mathbf{V} L^T)S = 0$

$\beta < 1$, $\mathbf{VW} = P_\alpha$

b). Duality principle for design of dynamical feedback

What The Approach Provides

- **Realistic statistical model of uncertainty**
  (accuracy characteristics are received in the state-space model with "separated" noises in sensors and actuators)

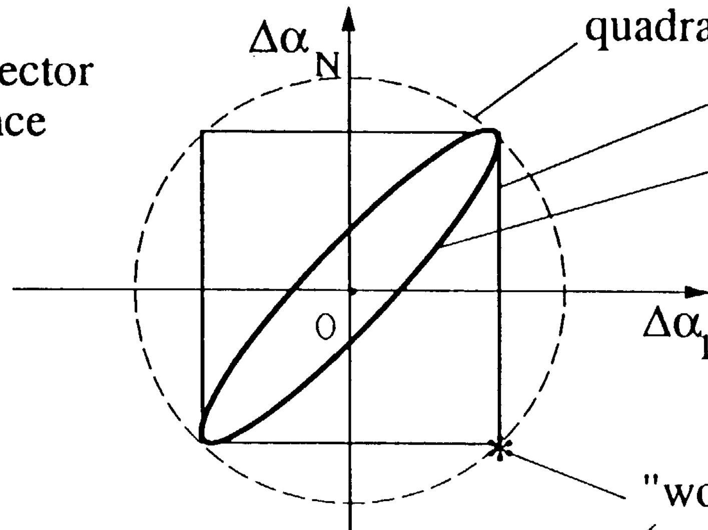
- **Active ID:** Optimization of open- and close-loop inputs directly with respect to robust control performance

- **Taking into account constraints on excitation**
  (desirable ID accuracy can be achieved with much less excitation, extremely important for experiments in the space)

- **Possibility to identify time-varying parameters**
  (in case of moving rigid payloads)

Advantages of "Post-ID" Model of Uncertainty

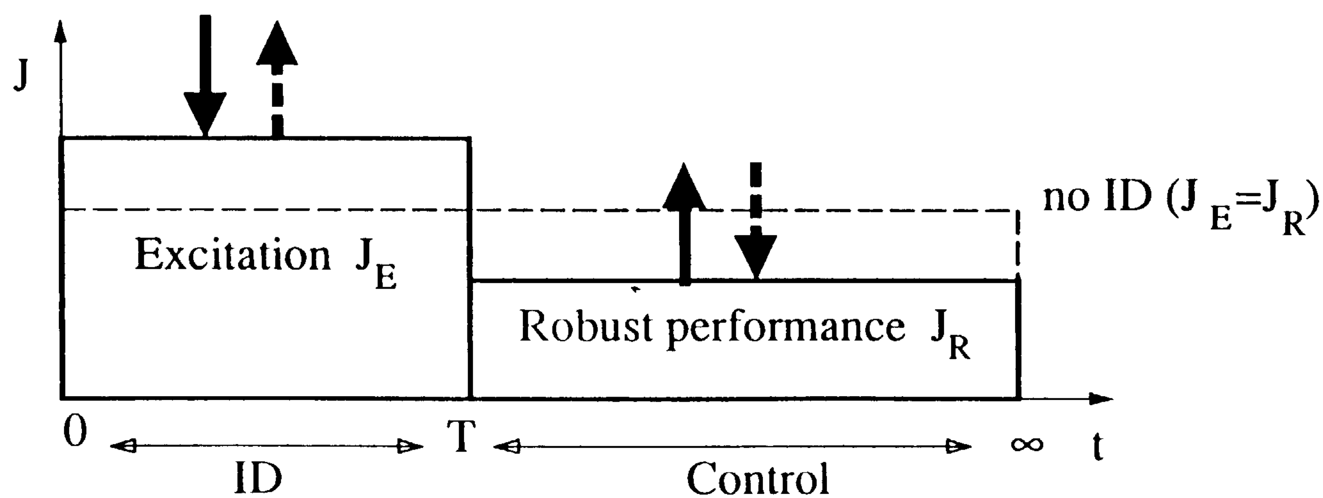
α is Gaussian vector with covariance matrix P_α



- **Reveals "cost" of different errors**
- **Reveals covariances between parameters**
- **Prevents non-realistic "worst combination" of parameters**
  (degrades conservatism of robust control)

Advantages of Optimization

- **Further degrading the conservatism**
- **Better coping with "difficulties" in the model, e.g. close modes** *(excitation in optimal directions amplifies the difference between modes)*
- **The best compromise between excitation and robust control performance**



$J = J_R + pJ_E$ where p is a "price" of ID
All J are quadratic forms

Practical Realization

- **Simulation of identification and robust control processes for MACE** *(important for confirming convergance of parameter estimates to "true" ones)*
- **Ground experiment**
- **Experiment in space**