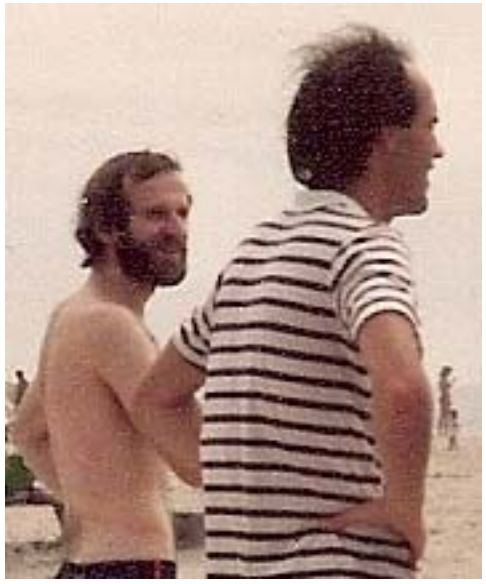
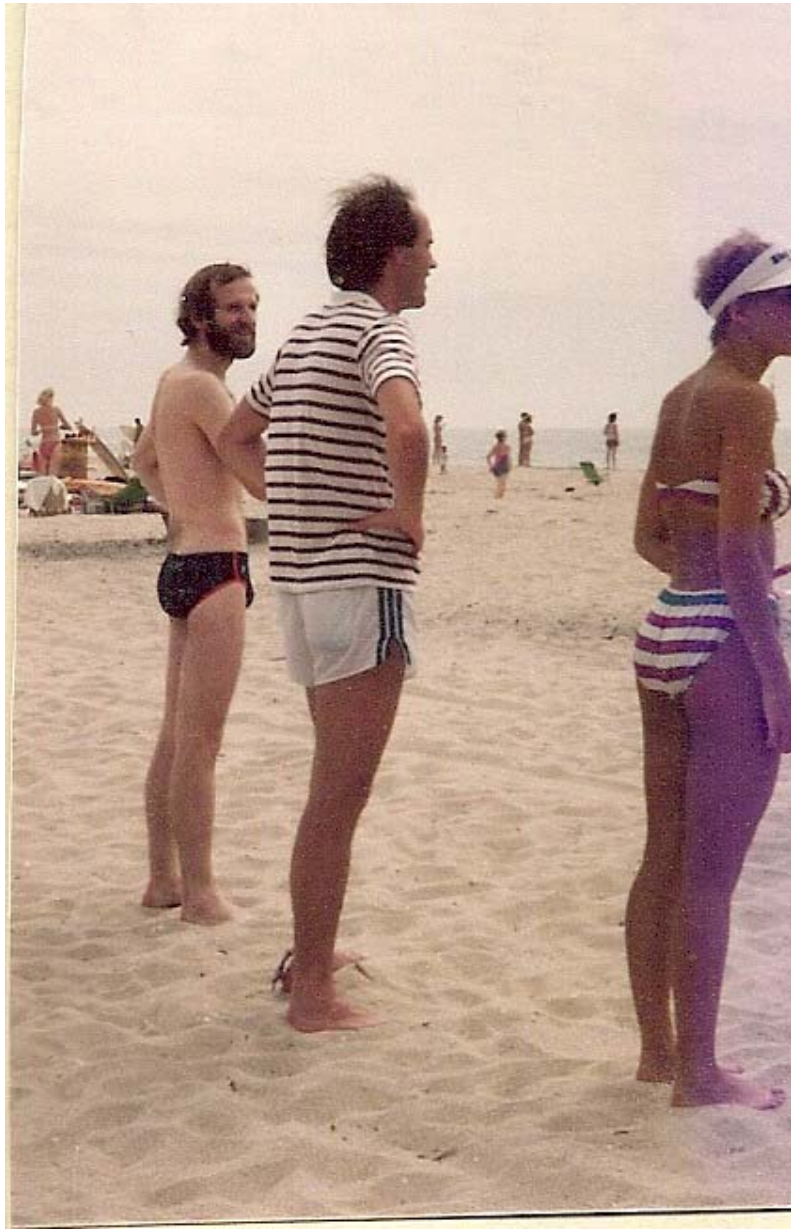
Early Caltech years



Including: Sigurd going through old emails

Tomorrow: Focus on research

THE CALTECH START



September 1983: Caltech ChE Beach Party at Huntington Beach

CALIFORNIA INSTITUTE OF TECHNOLOGY

CHEMICAL ENGINEERING 206-41

11 July 1984

TO: R. Colberg
C. Economou
P. Grosdidier
K. Jordan
D. Laughlin
J. Mandler
D. Rivera
T. Skjellum
S. Skogestad
H. Tung
M. Uchida
C. Webb
E. Zafiriou

FROM: M. Morari

Attached is a list of group committees, research projects and seminar topics for this summer/fall. I would like to meet with you

THURSDAY, July 12 -- 4:00 p.m.
113 Spalding

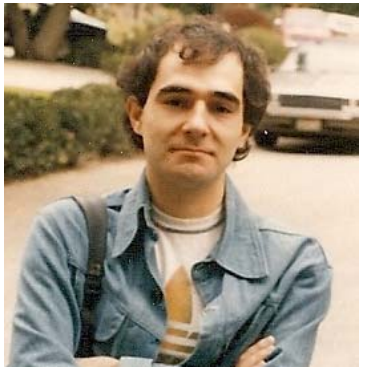
to discuss your responsibilities. I plan to retain this distribution for the next year. Please think carefully about possible additions, changes and improvements.

Nonlinear Systems: C. Economou

- Theoretical treatment using nonlinear operators
- Application to biological systems, combustion, crystallizers, batch processes
- Simplified implementation using steady state model or gain-scheduling

Resilience/Design of Energy Management Systems: R. Colberg

- Relationship between total exchanger area and resilience
- Minimum area problem
- Revamp synthesis
- Dynamic resilience



Large Scale System Decomposition: P. Grosdidier

- Block interaction measures
- Application to crossweb control

Modelling/Model Reduction/Identification:

Rivera:

- Multivariable model characteristics important for control
- Optimal process inputs for identification
- Effect of condition number on identifiability

Rivera/Skogestad:

- PID paper: Graph with allowable deadtime error for PID

Rivera/Skogestad/Laughlin:

- PI and Smith Predictor: Tuning rules under uncertainty

Tung:

- Transfer function models from collocation models

Discrete Time Systems:

Zafiriou:

- Sampling time selection
- Multivariable deadbeat - also impulse response formulation
- Impulse vs. step response formulation
- Problem formulation for transfer matrices with elements with drastically different dynamics
- RHP zero factorization from IR model
- Robust discrete IMC design

Webb(Zafiriou):

- LP/QP formulation with constraints
  - impulse vs. step response model
  - taylor made algorithm
  - control logic, e.g. override, split range
  - start-up, emergency shut-down
  - stability and robustness

Adaptive IMC: Jordan

- STR - IMC interpretation
- MIMO - STR: IMC technique for handling multiple delays
- Influence of condition numbers on identifiability. How to guarantee multivariable "positive gain"?
- Gain scheduling

Continuous Robust IMC Design: Laughlin (Skogestad)

- Brosilow/Chen technique
- Doyle/Francis technique → IMC implications?
- Open-loop unstable systems
- Coprime factorization technique?
- IMC vs. Loop Transfer Recovery

Dynamic Resilience: Skogestad

- Continue Holt's work on RHP zeros and delays
- Synthesis technique vs. structured uncertainties
- Resilience assessment of open-loop unstable systems
- Single distillation column resilience assessment

Tung/Skogestad:

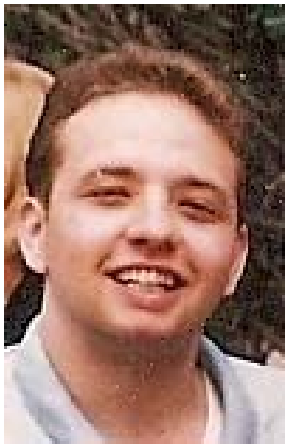
- Multiple column resilience assessment
- ICI reactor resilience assessment
- Dynamic implications of steady state resilience conclusions

Methanation Reactor - Experimental System

- Main responsibility with Mandler and Webb but application of theoretical findings expected from most other group members

Distributed Processing for Chemical Engineering Applications: Skjellum/Douma

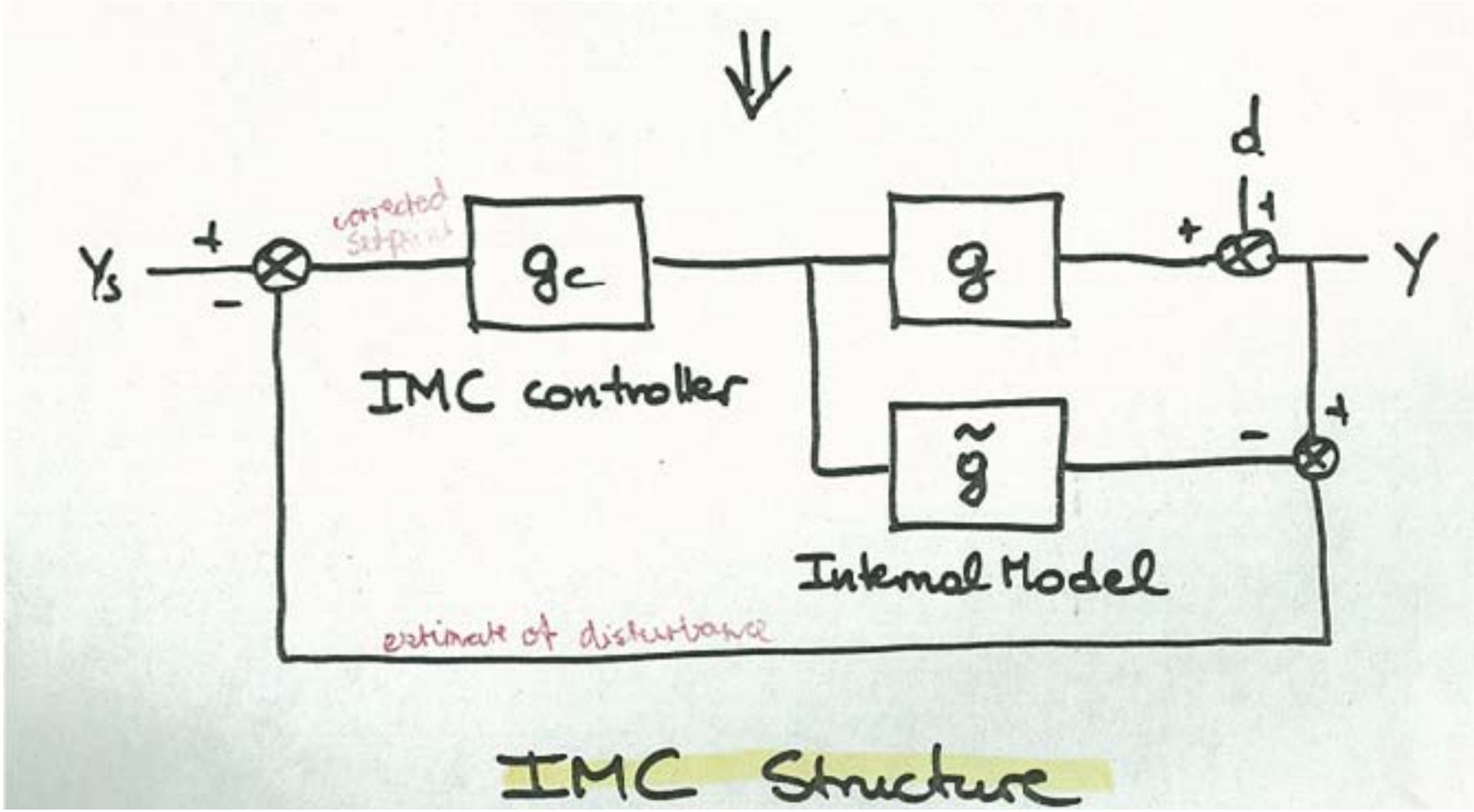
Crystallizer Literature Survey
or Thermodynamic/Kinetic design feasibility analysis: M. Uchida



PROCESS DESIGN & CONTROL RESEARCH GROUP

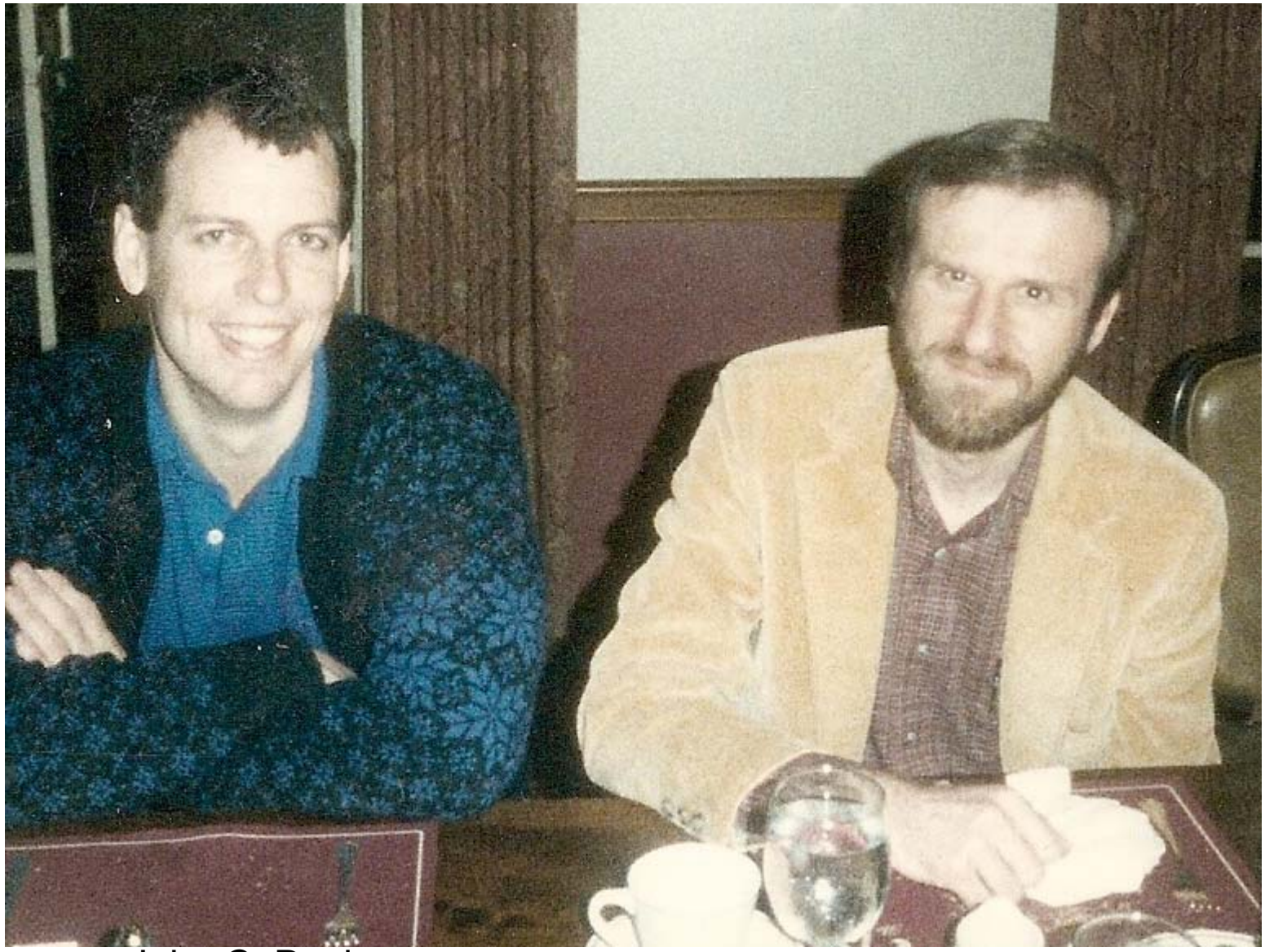
Seminars: Summer 1984 (incomplete list)

Colberg:	Heat Exchanger Network Synthesis and Resilience
Laughlin:	Robust Control System Design
Webb:	LP/QP Implementation of IMC
Skjellum:	Distributed and Parallel Processing
Zafiriou:	Sampling Time Selection MIMO Deadbeat Controllers
Jordan:	Adaptive Control

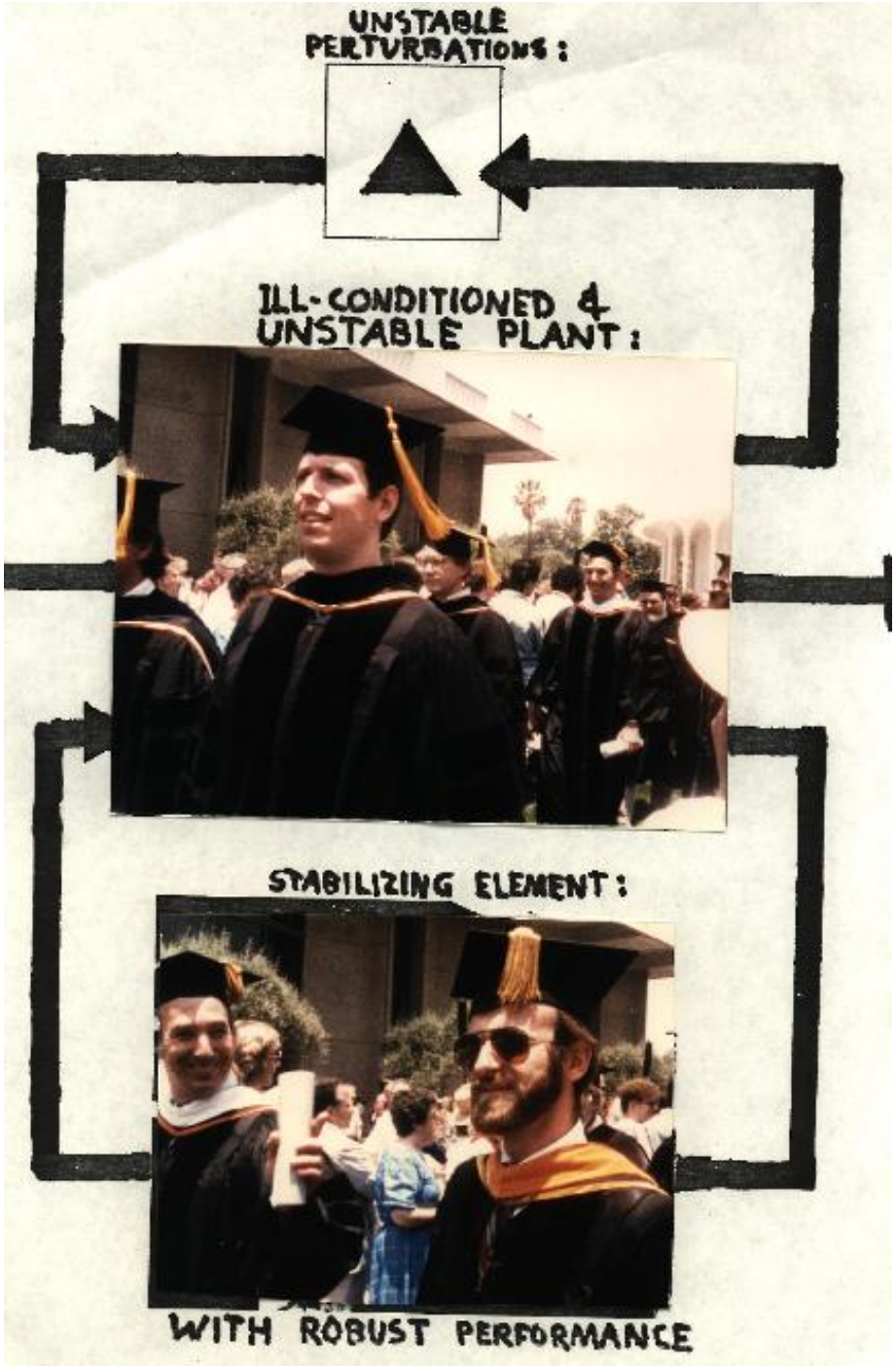


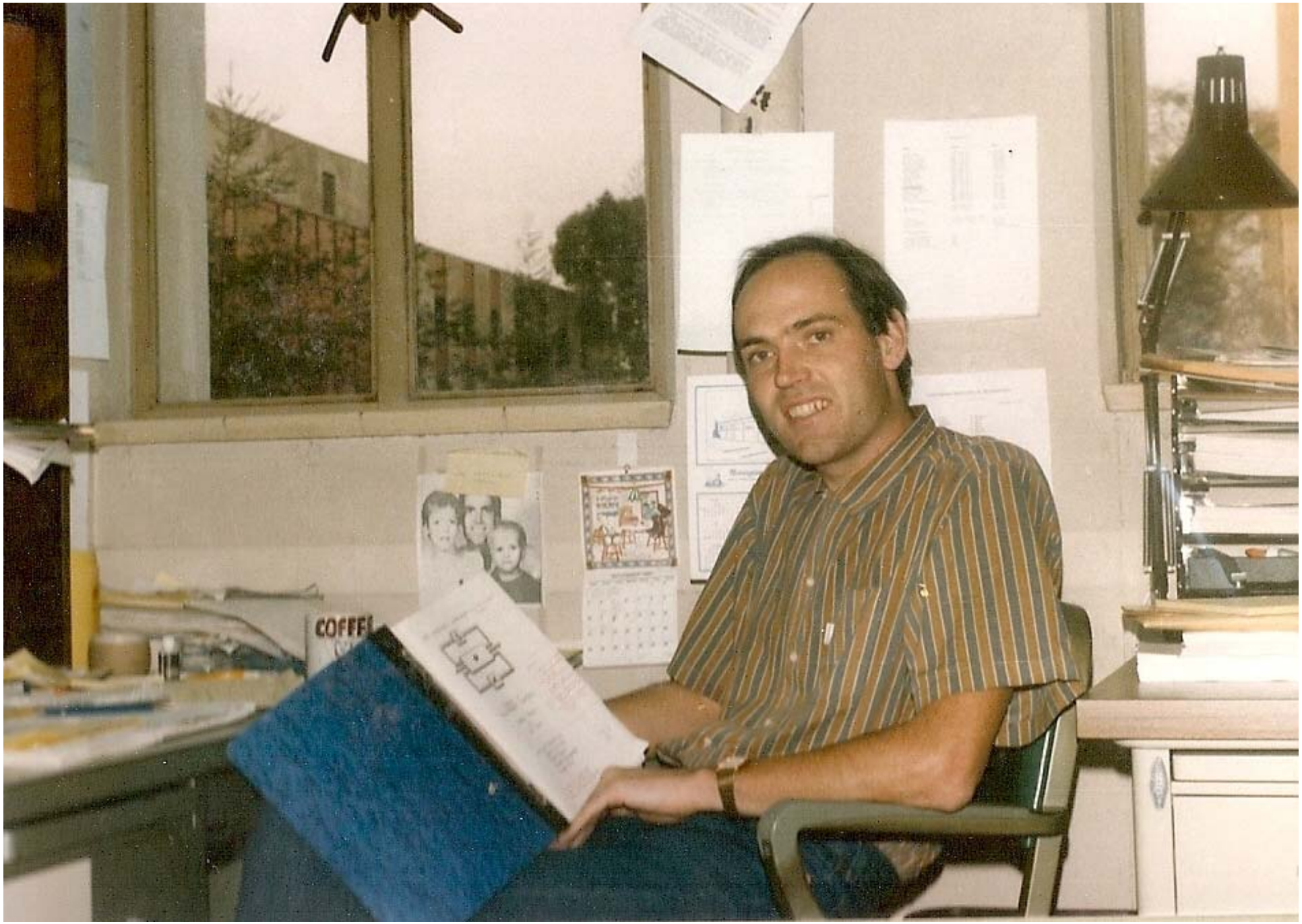
IMC Structure

The IμC team



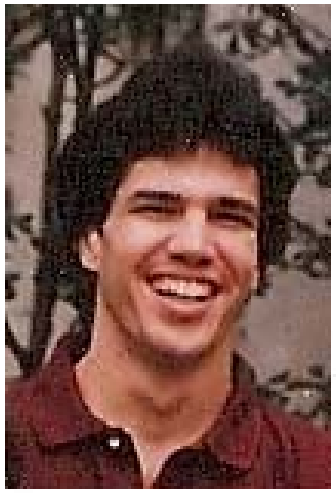
John C. Doyle


UNSTABLE
PERTURBATIONS :
ILL-CONDITIONED &
UNSTABLE PLANT :
STABILIZING ELEMENT :
WITH ROBUST PERFORMANCE


COFFEE

CALIFORNIA INSTITUTE OF TECHNOLOGY

CHEMICAL ENGINEERING 206-41



July 11, 1986

TO: P. Campo
M. Creed
R. Colberg
P. Engel
D. Laughlin
D. Lewin
J. Mandler
D. Rivera
A. Skjellum
S. Skogestad
C. Webb
E. Zafiriou

FROM: M. Morari

SUBJECT: Group responsibilities

Below is an updated list of responsibilities for the rest of the

Committees for 1986 (underline denotes person with main responsibility

Visitor and New Students Committee:	Skogestad, Lewin
Literature Circulation Committee:	Laughlin, Rivera
Microcomputer and Computer Peripheral Committee:	Skjellum, Webb
Remodelling Committee:	Vacant
Group Seminar Committee:	Creed, Colberg
MicroVAX Committee:	Campo, Skjellum
CRELLIN Computer Committee:	Zafiriou, Webb
CONSYD Committee:	Webb, Rivera
Process Design Software Committee:	Colberg, Engel

ORGANIZATION AND EQUIPMENT

The Process Control and Design Research Group is a part of the Division of Chemistry and Chemical Engineering at the California Institute of Technology. The scientific staff consists of Professor Morari and approximately ten Ph.D. students. On the average, about three postdoctoral fellows, research fellows and visiting associates, and two to three undergraduate students cooperate with the staff.

The group's computational and experimental equipment includes:

- One MicroVAX II (VMS operating system, 10 MByte memory, 70 MByte hard disk)
- Three IBM 9000 (M68000 Processor, 1 MByte memory, 20 MByte hard disk, A/D and D/A peripherals)
- One IBM PC-AT (1MByte memory, 30 MByte hard disk, EGA graphics)
- Three IBM PC-XT (10/20 MByte hard disk, different graphics boards)
- Two graphics terminals
- Various penplotters, printers and terminals

Other equipment available on campus is used routinely:

- VAX 11/780 (VMS-operating system)
- Several VAX 11/750 (VMS and UNIX-operating system)
- Various microcomputers (MacIntosh, IBM PC-AT)
- Various printers, plotters, and other peripherals.

All equipment is linked either via the campus Ethernet or serial lines. Several machines can be accessed from locations outside Caltech via modem, BITNET or ARPANET.

To test some of the theoretical process control developments, a simple two-tank mixing system and a complex methanation reactor are available.

EDUCATIONAL ACTIVITIES

All Ph.D. students are required or advised to take a number of intermediate level chemical engineering courses to broaden their background. Typically they are also enrolled in courses in other areas (e.g., mathematics, operations research, computer science and electrical engineering) to prepare them better for their research.

The members of the group are involved actively in the organization and teaching of annual systems and control courses which are offered jointly by Chemical and Electrical Engineering and are attended by students from several Divisions of the Institute. These graduate level courses are currently being restructured because of the addition of two faculty members in this area in electrical engineering (John C. Doyle and Athanasios Sideris). Annually six courses (each 10 weeks in length) are offered covering the following broad areas:

- Linear system theory
- Factorization approach to control system synthesis
- H_2-optimal and linear quadratic Gaussian optimal control
- H_∞-optimal control
- Internal model control
- Model uncertainty and robustness
- Structured singular value (μ) analysis and synthesis
- Control of nonlinear systems
- Adaptive control
- Applications and case studies on systems from chemical, mechanical, electrical and aeronautical engineering.

The following primary reference books are used to supplement an extensive set of notes:

A Course in H_∞ Control Theory by B. A. Francis, Springer Verlag, Berlin, 1987.

Linear Optimal Control Systems by H. Kwakernaak and R. Sivan, Wiley-Interscience, New York, 1972.

Robust Process Control by M. Morari, E. Zafiriou and C. Economou, Springer Verlag, Berlin, 1987.

Control System Synthesis: A Factorization Approach by M. Vidyasagar The MIT Press, Cambridge, 1985.

Actually:
Prentice Hall, 1989

ZPLOT, CONSYD, RESHEX, ROBEX

SOFTWARE DEVELOPMENT

Over the years we developed several software packages to facilitate the dissemination of our research results. The packages were designed to meet the dual demands of education and academic research. Thus, emphasis in their development was placed both on ease of use and the incorporation of the most modern design techniques.

The largest of these packages is CONSYD (CONtrol SYstem Design) [61]. Dozens of students and researchers both here at Caltech and at the University of Wisconsin have contributed to CONSYD over a period of about eight years. It is continually being improved, with new design techniques added as they are developed.

The package is uniquely suited to a wide range of users in the chemical industry. Besides conventional control techniques, it includes capacities of interest to chemical engineers such as the ability to work with systems containing time delays, non-linear systems, and an emphasis on frequency domain techniques where sensitivity and robustness analysis techniques exist. At the same time CONSYD still maintains the ease of use which is necessary for educational situations.

In the last decade many techniques for the synthesis and analysis of heat exchanger networks (HENs) have been developed. However, the "pencil and paper" techniques are awkward for the large problems encountered in practical industrial situations, and the "automatized" computer techniques have limited capabilities to accommodate the special requirements of the design engineer. RESHEX is a prototype program [29,30] where the computer techniques are significantly enhanced in terms of versatility to meet the practical needs of the design engineer. All functions including utility and area targeting, network synthesis, evolutionary network development, resilience analysis, and economic optimization, are available.

ROBEX (ROBust control synthesis via EXpert system) is a new generation of software which aims at making some of the most advanced robust controller design techniques available to users who know much about the physical process and the practical requirements but little about control theory (e.g., plant operators). The prototype is limited to single-input-single-output systems; the long term goal is to address multivariable systems.

Zoltan Szakaly (Zplot)

Claudio Scali (visitor)


DAVID PRETT
CARLOS GARCIA
DOMINIQUE BONVIN
MANFRED MORARI

Caltech group After 1987

- Email highlights

1987: Start of “external” emails…

Date: 10 April 1987, 10:28:03 ECT
From: Sigurd Skogestad +47-7-594154 SKOGESTA at NORUNIT
To: MM%IMC at CITCHEM

Hello Manfred,

I would be happy to get your list of people who can be reached by BITNET. You and Claudio are the only addresses I've got so far.

Here in Norway everyone is leaving on their long (10 days) Easter vacation. However, we are going to stay in Trondheim. Please say hello to Marina and the group members. By the way, are you considering coming to Trondheim in connection with your trip to Europe this summer? You will be pretty close when you go to Denmark.

Best wishes,
Sigurd.

April 1987: Manfred's 3 email friends

Date: Fri, 10 Apr 87 10:21:20 PDT
From: mm@CITChem.Bitnet (Manfred Morari)
Message-Id: <870410102120.01k@Xhmeia.Caltech.Edu>
Subject: BITNET etc.
To: Skogesta@norunit.bitnet

Sigurd,

Currently i am not planning to come to Trondheim. With all my detours
I am not sure I can fit it in.
I did not get your RGA paper response yet

I actually do not have many BITNET addresses.
All group members you can reach
at the same address: WEBB, DRL (Lewin), DL (Laughlin), LFL (Lionel Laroche), PC (campo) etc.

BITNET Brad Holt : C5254@UWAV4.bitnet
ARPANET Harmon Ray (Wisconsin)
RAY@CHEWI.CHE.WISC.EDU
ARPANET Evanghelos ZAFirioiu zafiriou@ra.umd.edu

Regards, Manfred

11 Nov. 1988: Fax machine installed at Caltech

Received: from imc.caltech.edu by Romeo.Caltech.Edu with VMSmail ;
Date: Fri, 11 Nov 88 10:15:31 PST
From: mm%imc.caltech.edu@CitRomeo.Bitnet
Message-Id: <881111101531.21400d0f@Romeo.Caltech.Edu>
Subject: FAX number
To: **zafiriou**%chemserv.eng.umd.edu%imc.caltech.edu@CitRomeo.Bitnet,
ray%CHEWI.CHE.WISC.EDU%imc.caltech.edu@CitRomeo.Bitnet,
Skogesta@Norunit.BITnet,
nett%GE-CRD.arpa%imc.caltech.edu@CitRomeo.Bitnet, **S@ICNUCEVM**.BITNET,
CERDLDL@TECHNION.BITNET

A FAX machine has been installed for ChE at Caltech

(818)568-8743

Manfred Morari

This important announcement goes to all of Manfred's, by now, 6 email friends

Feb 1989: Manfred goes skiing

Date: Mon, 13 Feb 89 15:46:54 PST
From: lionel%imc.caltech.edu\Hamlet.Bitnet
Subject: PROCESS files.
To: skogesta\norunit.bitnet

Sigurd

Thank you for your help on the PROCESS files.

Today is a special day: Manfred went skiing with some other professors and the rest of the group is working back here. Everything is so quiet$

Henrik and I are moving forward: the simulator will very soon have the sparse solver included, and it will be then much faster. I am looking forward to be able to use it on some spcefic examples.

Say hi to Anne-Lise and your kids.

Lionel

April 1989: Europe calls

From skoge Fri Apr 28 09:29:13 1989
To: mm%imc@citromeo.bitnet, skoge
Subject: ACC89

Hello Manfred,

I just returned from the European Cache-conference in Erlangen. There were a few good papers, in particular some of the work from Stuttgart and some people from German companies (Bayer). Most of the papers were on AI and process simulation and not too interesting. **Several people asked me if you were going to accept a position at Dortmund, but I gather you have decided not to.**

See you.

Sigurd.

June 1989: Gossip from Tony

From tony%imc.Caltech.Edu%CitRomeo.Bitnet@runix.runit.sintef.no Thu Jun 15 03:04:35 1989
To: <skoge@kjemi.unit.no>
X-Originator: tony%imc.Caltech.Edu@CitRomeo.Bitnet (Tony Skjellum)

Dear Sigurd, I am very happy to hear back from you!

I, unfortunately, will not get to go to Pittsburgh -- Manfred only wants to send me there during the Winter.

I have finished interviewing and have accepted employment at **Lawrence Livermore National Laboratory** in Livermore, California (40 miles east of Oakland and 30-40 miles SE of Berkeley). My supervisor will be Linda Petzold (Ms. DASSL), and I will

work on massively parallel computation as a continuation of current research interests... **I hope to start by the end of this calendar year and MM seems to believe this is possible as well.**

I'm sorry to hear that some of your AIChE papers were rejected. My one, humble, paper was accepted. I gues MM would be pissed, because he isusually getting all of his papers accepted. I hope to see you there, anyway. Why wouldn't they accept the DB paper. It seems like a very interesting topic.

As for Jay, Manfred now compares him with you and he has become the new hero of the group.

Jay's work on measurement selection seems to please Manfred and also be going very well on an objective scale too.

As for Frank, he doesn't work very hard and Manfred isn't too happy, I think. He is lucky he didn't get nuked like Eric...

Sincerely,
Tony

23 Dec. 1989: Tony still around

From tony%imc.Caltech.Edu%CitIago.Bitnet@runix.runit.sintef.no Sat Dec 23 02:00:29 1989
To: skoge@kjemi.unit.no

Merry Christmas, Sigurd,

I am glad to hear of the fourth child's imminent arrival. Tell Anne-Lise how happy we are for her.

I am still at Caltech, killing bugs in my program.

Keep in touch.

Tony

PPS The group members have suggested potential names for your baby if it is a boy:

Manfred Skogestad (number 1 choice)
Franz Josef Skogestad (number 2 choice)
Jay Lee Skogestad (number 3 choice)
Tony Jay Skogestad

we didn't really consider girl names yet, but we'll get back to you on that.

March 1990

Process Control & Design Group

California Institute of Technology

Professor Manfred Morari

CURRENT GRADUATE STUDENTS AND THESIS PROJECTS

Name of Student and Undergraduate School	*Research Project*	*Degree*	*Start Date*	*Expected Graduation*
Bekiaris, Nikolaos (NTU, Greece)	Azeotropic Distillation	Ph.D.	9/89	12/93
Braatz, Richard (Oregon State University)	Robust Process Control With Minimum Modeling Effort	Ph.D.	9/88	12/92
Doyle, Frank (Princeton University)	Nonlinear Process Control	Ph.D.	9/86	12/90
Gelormino, Marc (University of Rochester)	State-Space Model Predictive Control	M.S.	9/87	(leaving 3/16)
Holcomb, Tyler (University of Texas)	Neural Networks for Process Control	Ph.D.	9/87	12/92
Laroche, Lionel (Ecole Polytechnique, France)	Homogeneous Azeotropic Distillation	Ph.D.	9/86	12/90
Lee, Jay (University of Washington)	Robust Inferential Control	Ph.D.	9/86	12/90
Raven, Douglas (University of Texas)	Robust Control of Constrained Systems	Ph.D.	9/89	12/93
Skjellum, Anthony (Caltech)	Concurrent Dynamic Simulation	Ph.D.	6/84	5/90
Jacobsen, Elling (NTH, Norway)	Distillation Control	Special	1/90	7/90
Lundstrom, Petter (Royal Inst. of Technology, Sweden)	Multivariable Control of Distillation Columns	Special	1/90	7/90
Secchi, Argimiro R. (COPPE/UFRJ)	Concurrent Dynamic Simulation	Special	2/90	6/91

May 1992. To group: “if you take vacations at all..”

****

>From morari@macpost.caltech.edu Wed May 6 14:59:10 1992
Subject: VAcations etc.
To: MM_group@mozart
From: Manfred Morari <morari@macpost.caltech.edu>
Status: RO

Would you please inform Patricia of any intended vacation or interview or similar absence fo two days or longer, giving her departure as well as return times and dates as well as an emergency contact.

For your info. I will be gone for vacations during the last week of August and the first week in September. I will also be gone to IMA in Minneapolis for much of September. It would be good if you planned to take vacations at the same time if you take vacations at all..
Manfred Morari,Chem.Eng.210-41,
Caltech,Pasadena,CA 91125
phone (818)356-4186, fax (818)568-8743

****

1994: ETH calls

From mmorari@cheme.caltech.edu Tue Mar 8 00:56:05 1994
To: skoge@kjemi.unit.no
From: Manfred Morari <mmorari@cheme.caltech.edu>
Date: Mon, 7 Mar 94 15:59:51 -0800

Dear Sigurd:

After long consideration, I have decided after all to accept the offer from ETH and to take on the succession of M. Mansour in Zurich. I will be leaving from here May 15 and Marina will follow in August. For the time being, I am going to take a one year leave of absence and if I cannot adjust back to old Europe or if Marina finds it unbearable, we'll be back in a year. Needless to say, I am going to be back in the US many times during the next year, both to look after students who stay here as well as to attend conferences.

Best regards and best wishes also to your family,
Manfred

On inventing MPC

From skoge Wed Jun 8 11:23:09 1994

ADCHEM'94, Kyoto, Japan, 25 - 27 May 1994.
****

Manfred Morari's plenary on control:

The best of the plenaries.

He said on MPC that the main difference between MPC and optimal control from the 60's was the finite horizon. He claimed that finite horizon was not such a good idea after all, and that therefore noone wants to take the honor for inventing MPC anymore.

CONGRATULATIONS!

September 1983: Caltech ChE Beach Party at Huntington Beach