

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: December 5, 1979

Project Title: Optimization of a Vehicle's Control System and Geometry

Project No: E-21-E12 (Sub-project under E-21-E00/Paris/EE)

Project Director: Dr. V. K. Jain

Sponsor: Naval Coastal Systems Center; Panama City, FL 32407

Agreement Period: From 11/19/79 Until 6/15/81
(Delivery Order Term)

Type Agreement: Contract No. N00612-79-C-8004, Delivery Order No. HR-12

Amount: \$65,787

Reports Required: Bimonthly Status Reports; Tasks 1 and 2 First and Second Interim
Status Reports; Tasks 1 and 2 Final Reports; Tasks 1 and 2
Computer Program Card Decks

Sponsor Contact Person (s):

Technical Matters

Contractual Matters
(thru OCA)

Office of Naval Research
Resident Representative
325 Hinman Research Building
Georgia Institute of Technology
Atlanta, GA 30332

Defense Priority Rating: DO-C9 under DMS Reg. 1

Assigned to: Electrical Engineering (School/Laboratory)

COPIES TO:

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SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 11/11/83

Project No. E-21-E12 (under E-21-E00/Paris/EE)

School/~~Lab~~ Electrical Engineering

Includes Subproject No.(s) _____

Project Director(s) Dr. D. T. Paris (Project Director was Dr. V. K. Jain who is no longer at GIT)

GTRI / ~~GKR~~

Sponsor Naval Coastal Systems Center, Panama City, FL

Title Optimization of a Vehicle's Control System

Effective Completion Date: 6/15/81 (Performance) 6/15/81 (Reports)

Grant/Contract Closeout Actions Remaining:

- None
- Final Invoice or Final Fiscal Report
- Closing Documents
- Final Report of Inventions
- Govt. Property Inventory & Related Certificate
- Classified Material Certificate
- Other _____

Continues Project No. _____

Continued by Project No. _____

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NAVAL COASTAL SYSTEMS CENTER
OMNIBUS R&D PROGRAM
CONTRACT NO. N00612-79-C-8004

Bimonthly Status Report

121 117 5 1/31/80

Order Number: HR-12 Title: Optimization of a Vehicle's Control System
and Geometry

Task Leader: V. K. Jain

Institution: Georgia Institute of Technology/University of South Florida

Participants: Dr. A. V. N. Rao, R. W. Kautz, J. E. Joyner

A. SUMMARY STATEMENT OF WORK COMPLETED DURING THE PAST TWO MONTHS

The focus of the study in January 1980 has been on a deeper theoretical
understanding of, and on how improvements can be made upon, the Jain-Lawdermilt [1],
and Jain-Logston [2] optimization procedure for geometry parameters of under-
water vehicles.

An extensive review of optimization techniques was performed (and is still
underway), encompassing conjugate gradient techniques, quasi-Newton methods
(Luenberger [3]). A general survey of "Problems and Techniques in Constrained
Optimization" by Raush [4] was studied. This work was followed by more detailed
studies presented by Bard on a "Comparison of Gradient methods for the solution
of nonlinear Parameter Estimation Problems" [5] and by Dennis and More on
"Quasi-Newton Methods, Motivation and Theory" [6].

The result of these studies is a clearer understanding of the theory and
underlying difficulties of parameter optimization procedures. Some preliminary
conclusions are the following:

•The Jain-Lawdermilt-Logston procedure should be further improved.

•A designability criterion should be evolved to aid the engineer

so that he may assess the bounds of performance before using the

computer program for optimization.

B. WORK SCHEDULE STATUS

Further work underway.

C. BRIEF STATEMENT OF PLANNED WORK FOR THE NEXT TWO MONTHS

The improvement of the Jain-Lawdermilt-Loqston procedure will be investigated.

D. PROBLEM AREAS

N/A

E. FUNDS EXPENDED

To Date: \$1,914.00

This Two Month Period: \$1,914.00

Funds Remaining: \$63,873.00

Percent of Funds Expended: 3%

Percent of Task Completed: 3 to 4%

NAVAL COASTAL SYSTEMS CENTER
OMNIBUS R&D PROGRAM
CONTRACT NO. N00612-79-C-8004

Bimonthly Status Report (Feb. 1 to March 31, 1980)

Order Number: HR-12 Title: Optimization of a vehicle's Control System
and Geometry

Task Leader: V. K. Jain

Institution: Georgia Institute of Technology/University of South Florida

Participants: Dr. A. V. N. Rao, R. W. Kautz, J. E. Joyner

A. SUMMARY STATEMENT OF WORK COMPLETED DURING THE PAST TWO MONTHS

Local convergence of the Jain-Lawdermilt-Logston optimization procedure
was studied and established from theoretical considerations for the special
case $dx/dt = B(\theta)x + C(\theta)u(t)$ (pertaining to the linearized vehicle dynamics).
The applicability of this result is currently being examined. A similar
study of the more general case, $A(\theta) dx/dt = B(\theta)f(x,u,w)$, more important
for the objectives of the overall project, will be carried out next.

Secondly, the possibility of evolving a designability criterion -- to
aid the designer -- was investigated. Making use of a Liapunov type of function,
a basis for such a criterion was proposed by us. Its merits as well as
drawbacks, such as the lack of a systematic way for finding the Liapunov
function, will be evaluated.

Thirdly, the study and development of a Nonlinear Multiple-Object-Function
Newton program has been started. Over the next two months example runs will
be made for the Naval Coastal Systems Center. The effect of additive noise
vector $w(t)$ on actual convergence will be examined through simulation.

B. WORK SCHEDULE STATUS

Further work underway.

C. BRIEF STATEMENT OF PLANNED WORK FOR THE NEXT TWO MONTHS

a) Local convergence properties of the optimization procedure for the
general model will be studied

b) Evaluation and modification of the designability criterion will be
carried out

c) Effect of noise on the nonlinear MOFNM algorithm will be investigated

D. PROBLEM AREAS

N/A

E. FUNDS EXPENDED (Approximate)

To Date: \$9,108

This Two Month Period: \$7,194

Funds Remaining: \$56,673

Percent of Funds Expended: 14%

Percent of Task Completed: 13 to 14%

NAVAL COASTAL SYSTEMS CENTER
OMNIBUS R&D PROGRAM
CONTRACT NO. N00612-79-C-8004

Bimonthly Status Report (June 1 to July 31, 1980)

Order Number: HR-12 Title: Optimization of a Vehicle's Control System
and Geometry

Task Leader: V. K. Jain

Institution: University of South Florida Participants: Dr. A. V. N. Rao,
Dr. E. Verriest, R. W. Kautz

A. SUMMARY STATEMENT OF WORK COMPLETED DURING THE PAST TWO MONTHS

1. Further study of the designability criterion was carried out. Our work
now provides a basis for the determination of the ϵ -designability of the
vehicle's parameters relative to a given trajectory and associated quadratic
criterion. Although the theory developed is quite general, the particular
case where the vehicle dynamics is linearized and the unknown parameters
appear linearly, has been pursued in sufficient detail. A comparison has
also been made with the works of Chang and Peng [1] and Vinkler and Wood [2],
who have used similar theoretical tools. A report on this work will be
prepared for NCSC over the next two months.

2. An extensive series of tests were conducted on the Multiple-Object-
Function Newton Method (MOENM) to explore its limitation and strengths and
to help the user of the program MOF toward successful design. These tests
have led to certain broad guidelines in respect to a priori parameter values,
steady-state compatibility of desired trajectories, and initial stability.

3. Extension of MOENM to the case where the desired responses are specified
(rather than the state trajectory) has been started.

4. Study of a particular design problem specified by NCSC is underway.

B. WORK SCHEDULE STATUS

Further work underway

C. BRIEF STATEMENT OF PLANNED WORK FOR THE NEXT TWO MONTHS

(a) A Report on designability criterion will be written

(b) The examples of optimum design using MOFNM, including some aircraft and submerged vehicle studies, will be completed and documented in a report to NCSC.

(c) Extension of MOFNM to the desired measured responses case will be pursued further.

D. PROBLEM AREAS

N/A

E. FUNDS EXPENDED

To Date: \$25,304.00

This Two Month Period: Approximately \$10,770

Funds Remaining: \$36,781.00

Percent of Funds Expended: 17.4% (of \$62,085)

Percent of Task Completed: Approximately 17%

NAVAL COASTAL SYSTEMS CENTER
OMNIBUS R&D PROGRAM
CONTRACT NO. N00612-79-C-8004

Bimonthly Status Report (Aug. 1 to Sept. 30, 1980)

Order Number: HR-12 Title: Optimization of a Vehicle's Control
System and Geometry.

Task Leader: V. K. Jain

Institution: University of South Florida

Other Participants: Dr. A. V. N. Rao, Dr. E. Verriest, R. W. Kautz.

A. SUMMARY STATEMENT OF WORK COMPLETED DURING THE PAST TWO MONTHS

1. The work on designability criterion was completed together with an investigation of its inter-relationship to guaranteed-cost-control by Chang and Peng, and Vinkler and Wood. A report on the work done was submitted to NCSC.
 2. A second report, on the further development in MOFNM (multiple object function Newton method for design of control and geometry parameters), was also submitted. The new developments include a) the concept and implementation of consistent design trajectories, b) the inclusion of control-cost in the cost function, and c) filtering.
 3. Significant progress has been made in EXTENSION of MOFNM to the case where desired responses (rather than state trajectories) are specified.
 4. Solution of a task problem, the latter provided to us by NCSC, was completed and submitted to NCSC.
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B. WORK SCHEDULE STATUS

Further work is underway.

C. BRIEF STATEMENT OF PLANNED WORK FOR THE NEXT TWO MONTHS

(a) Further work on item 3 on page 1 will be carried out.

(b) More design tasks, as specified by NCSC, will be carried out.

(c) A theoretical investigation of the possibility of using numerical derivatives in MOFNM will be carried out.

(d) The reports on "Designability" and "Extensions and Applications to MOFNM" will be revised in light of NCSC comments.

D. PROBLEM AREAS

E. FUNDS EXPENDED

To Date:	Approximately	\$35,986
This Two Month Period:	Approximately	\$11,082
Funds Remaining:	Approximately	\$26,099
Percent of Funds Expended:	17.8% (of \$62,085);	58% to date
Percent of Task Completed:	18 %	; 58% to date

NAVAL COASTAL SYSTEMS CENTER
OMNIBUS R&D PROGRAM
CONTRACT NO. N00612-79-C-8004

Bimonthly Status Report (Oct. 1 to Nov. 30, 1980)

Order Number: HR- 12 Title: Optimization of a Vehicle's Control System
and Geometry

Task Leader: V. K. Jain

Institution: University of South Florida

Other Participants: R. W. Kautz.

A. SUMMARY STATEMENT OF WORK COMPLETED DURING THE PAST TWO MONTHS

1. Futher work on EXTENSION of MOFNM to the case where desired responses
(rather than state trajectories) are specified was done. Based on this
extended technique, a computer program for vehicle optimization is being
developed.
2. An in-depth study on optimization techniques using numerical derivatives
was carried out. A trial program is currently being developed along these
lines.
3. As a major case example of application of MOFNM the lateral control
system design of a jet aircraft was attempted. The desired response consisted
of a specified yaw-rate history. State trajectories consistent with the
specified yaw-rate response (for a set of initial parameter values) were
generated and a windowing technique was applied. The design resulting from
MOFNM program was found to be highly satisfactory and is being submitted
to NCSC.

B. WORK SCHEDULE STATUS

Further work is underway

C. BRIEF STATEMENT OF PLANNED WORK FOR THE NEXT TWO MONTHS

(a) Further work on items 1 and 2 on page 1 will be carried out

(b) More design tasks, as specified by NCSC, will be performed.

D. PROBLEM AREAS

E. FUNDS EXPENDED

To Date:	Approximately \$54,599
This Two Month Period:	Approximately 7,947
Funds Remaining:	Approximately 7,486
Percent of Funds Expended:	12.8% (of \$62,085); 87.9% to date
Percent of Task Completed:	13 % ; 88 % to date

NAVAL COASTAL SYSTEMS CENTER
OMNIBUS R&D PROGRAM
CONTRACT NO. N00612-79-C-8004

Bimonthly Status Report (Feb. 1, 1981 to March 31, 1981)

Order Number: HR-12 Title: Optimization of a Vehicle's Control System
and Geometry.

Task Leader: V. K. Jain

Institution: University of South Florida

Other Participants: R. W. Kautz, C. T. Tegreene

A. SUMMARY STATEMENT OF WORK COMPLETED DURING THE PAST TWO MONTHS

1. Extension of MOFNM to the case where desired responses are specified:

A computer program was written and is currently being tested.

A report entitled "Optimum design of circuits and systems" is being prepared for NCSC.

2. For the case where the relationships between hydrodynamic coefficients

and the geometry parameters are given in numerical form, a computer

program for vehicle optimization was written. It is partially

complete and is being applied to the RPV geometry design.

3. As another major case example the longitudinal control of a 747

aircraft has been implemented on MOFNM. The optimum design problem

is currently being studied for the effects of additive noise and for

optimum ascent rate command. Results of this study will be sent to NCSC.

An interim report entitled "Optimum design of underwater vehicle

control and geometry" was sent to NCSC which includes summaries of

recent design case examples and a brief exposition of the Square-Root

Variable Metric Method employed in NUMOF.

B. WORK SCHEDULE STATUS

Further work is underway

C. BRIEF STATEMENT OF PLANNED WORK FOR THE NEXT TWO MONTHS

(a) Further work on items 1 and 2 on page 1 will be carried out.

(b) Studies on the effect of additive plant noise and measurement noise
will be performed. Also, the design study on the 747 aircraft with
ascent-rate command will be performed.

D. PROBLEM AREAS

E. FUNDS EXPENDED

To Date:	Approximately \$59,209
This Two Month Period:	Approximately \$ 4,610
Funds Remaining:	Approximately \$ 2,876
Percent of Funds Expended:	7.4% (of \$62,085); 95.4% to date
Percent of Task Completed:	7 % ; 95 % to date

NAVAL COASTAL SYSTEMS CENTER
OMNIBUS R&D PROGRAM
CONTRACT NO. N00612-79-C-8004

Bimonthly Status Report (April 1, 1981 to May 31, 1981)

Order Number: HR- 12 Title: Optimization of a Vehicle's Control System
and Geometry.

Task Leader: V. K. Jain

Institution: University of South Florida
Other Participants: R. W. Kautz, C. T. Tegreene

A. SUMMARY STATEMENT OF WORK COMPLETED DURING THE PAST TWO MONTHS

1. For the case where the relationships between hydrodynamic coefficients
and the geometry parameters are given in numerical form, a computer
program for vehicle optimization was written. Its first version is
complete and was applied to the RPV geometry design. The program
employs numerically computed derivatives and a Square-Root Variable-
Metric method.

2. As another major case example the longitudinal control of a 747 air-
craft has been implemented on MOFNM. The optimum design problem was
studied for an ascent rate command. Results of this study will be
sent to NCSC.

B. WORK SCHEDULE STATUS

Further work is underway.

C. BRIEF STATEMENT OF PLANNED WORK FOR THE NEXT TWO MONTHS

Further work on items 1 and 2 on page 1 will be carried out.

D. PROBLEM AREAS

E. FUNDS EXPENDED

To Date:	Approximately \$61,800
This Two Month Period:	Approximately \$ 2,591
Funds Remaining:	Approximately \$ 285
Percent of Funds Expended:	4.2% (of \$62,085; 99.5% to date
Percent of Task Completed:	4 % ; 99 % to date