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CFD CODE SURVEY FOR THRUST CHAMBER APPLICATION

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ABSTRACT

In the quest to find analytical reference codes, responses from a questionnaire are presented which portray the current CFD program status and capability at various organizations, characterizing liquid rocket thrust chamber flow fields. Sample cases are identified to examine the ability, operational condition, and accuracy of the codes. To select the best suited programs for accelerated further improvements, evaluation criteria are being proposed.

INTRODUCTION

Numerous CFD programs have been developed which characterize liquid rocket thrust chamber flow fields and predict the associated performance. In the past a similar situation existed, leading to a competitive selection process, from which the well known two-dimensional kinetics (TDK) program and several boundary layer codes resulted. These programs were identified as reference programs and still serve in this capacity today. The CFD calculation procedures have not only matched this capability but already provide limited flow process characterizations which exceed the existing recommended methods. A selection of one or several of the best suited programs is of advantage to accelerate the simulation of specific physical mechanisms, where little or no capability exists. Limited funding resources can then be concentrated on these few chosen program candidates.

As indicated at the JANNAF Combustion Meeting at the Marshall Space Flight Center (MSFC) in 1988, a questionnaire was prepared and distributed to the propulsion community with a subsequent good response. A listing of the responding organizations is included in the appendix.

The furnished material has been used to construct a matrix which provides an overview of the operational CFD programs, their physical simulation capabilities, numerical solution techniques, and documentation, to name only a few categories.

In addition to the collected program information, some sample cases are identified which shall be executed by the codes to demonstrate the algorithm maturity and accuracy, and its application to combustion chamber and nozzle flows.

Of consequence are the presented criteria below, which may be used in the selection process for the most qualified CFD codes. This is projected to occur during the 1992/93 time frame. The parties planning to participate in the development of a reference program are requested to review the proposed selection approach and provide their comments, critique, or consent.

OBJECTIVE

The presented material should inform the propulsion community of the various existing CFD computer program capabilities and their operational status. This is the first step in a process leading eventually to the selection of the most advanced code(s) for the prediction of thrust chamber flow fields and the associated performance. Exposure of the programs to particular sample cases and a final test, with unknown results to the program operators, will be further milestones during this process. The identified sample cases and the proposed program evaluation criteria should be reviewed by the parties involved.

QUESTIONNAIRE RESULTS

The overall response to a questionnaire, which I prepared and distributed in the beginning of 1989, was very satisfactory, but extended over a long time period. Therefore, an update of the original information was initiated in September 1990 to include the most recent advances of the programs in question. The important information has been organized down to a very detailed level, and the results are presented in Table 1. It shall be noted that only problems related to the operation of liquid rocket thrust chambers, composed of the combustion chamber and the nozzle, are of concern here.

The key topics in Table 1 address the foundation of the code, followed by the physical process simulation capability, and the numerical solution methods used. The categories thereafter reflect primarily the validation status of the code, experience and success with specific problems, ease of preparing a case, and supporting elements to evaluate and display the results. Finally, information with regard to the program documentation, code availability, and computer oriented questions is displayed. The abbreviations shown in the columns represent abridged forms of the actual terminology which can be interpreted without difficulty by the readers who are somewhat familiar with the subject. Assistance in this matter can be found in Table 2.

From the survey it is evident that the CFD codes have achieved already a high level of physical process simulation; however, the advanced models are scattered in the matrix of Table 1. Examples of such advanced techniques refer to turbulence modeling via large eddies, spectral method discretization, jet breakup calculation, and droplet interaction in the spray regime. It is anticipated that the presented information will motivate the program developers to equip their codes with the latest methods.

BENCHMARK TESTING

It is the responsibility of every CFD code developer to expose his program to the most commonly known simple benchmark tests and prove that the program works for the basic flow simulation and the physical model features. Under basic features the treatment of incompressible, compressible, inviscid, laminar, low to high Mach number, shock capturing, two-dimensional, three-dimensional, steady state, time dependent, and geometry or grid dependent flows is normally recognized, while the simulation of turbulence, atomization, two-phase spray, vaporization, multi-species with chemical reactions, and heat transfer refers to the physical modeling.

SAMPLE CASES

To examine the program capability, maturity, and accuracy with respect to a thrust chamber flow simulation, the execution of sample cases shown in Table 3 is recommended. These sample cases are related to the basic flow conditions in a combustion chamber and nozzle, but also reflect situations which have been experienced in the past and which are of utmost importance. Attention is focused on the injector region, where flows from different injection elements produce a spray, sometimes with intentional stream striation arrangements for performance optimization and hardware protection. The flow pattern adjacent to the wall contour is another important domain in which turbulence dominates the viscous behavior and the heat transfer process. Based on the engine operation cycle, such as a regeneratively cooled concept or an expander cycle approach, the wall design and the near wall flow conditions serve different functions and are very different indeed. Thrust chamber flow start and shut-down, which are feed system driven, as well as the nozzle exhaust flow, interacting with the ambient air, are highly important conditions which need to be firmly comprehended.

To start this project, it is planned to form a group of experts from the government and industry shortly, which will provide explicit details for the uniform treatment of recommended sample cases. Initial and boundary conditions, basic and physical flow features, and recommended grids to run these cases will be specified. The format of the results for individual parameter, tabular, and graphic presentation will be identified also. Program solutions will be collected and compared with available measurements or other recognized data. The organizations which continue to advance their CFD programs are encouraged to participate in this activity.

CFD CAPABILITY GOAL

Ultimately, the requirements for a comprehensive CFD program, simulating the flow motion in a thrust chamber, must include the characterization of bi-propellants and two-phase flow undergoing liquid jet atomization, vaporization, propellant mixing, chemical reaction, flow expansion from low to high Mach numbers, viscous effects, and heat transfer processes. Steady-state and transient flow modeling for three-dimensional flows are mandatory. In the fluid spray regime the interaction between neighboring droplets must be simulated, especially for conditions below and above the critical point. Nozzle flow interaction with the ambient air during captive testing and during flight from the launch site to vacuum conditions in orbit is also imperative.

At this time, the developed computer programs use specific assumptions to overcome the deficiencies in the previously quoted areas of physical process descriptions more or less successfully. Experimental research programs and associated modeling activities are constantly underway to eliminate these shortcomings gradually. However, the new formulations are frequently 'hardwired' into the codes, and a transfer to other programs for technology sharing is rather difficult. To exchange advanced techniques quickly and efficiently, the new routines should be structured in modules with clearly identified interface parameters. Such an approach offers a special advantage when specific techniques, numerical or physical, need to be examined for their efficiency and accuracy. Using standard parameter nomenclature will definitely be effective.

Since some domains in a thrust chamber flow field require simulation with extensive details of the physical processes, while other areas are much simpler in character and can be described with less effort, a decoupling of the entire flow field at beneficial interfaces may offer an advantage and should be explored. One such interface could be at a place in the combustion chamber where the spray flow terminates and the expansion process starts. Here, the particular information of the entire injection process, which has been obtained from a detailed CFD solution, may be transferred to a subsequent quick and efficient CFD analysis. Certainly, a fully coupled solution is the goal; however, the provision of an interface, from a position of problem complexity and current computer limitations in core and execution time, should not be disregarded.

SELECTION CRITERIA

The selection of one or several CFD programs to serve as reference codes is of paramount importance and must be conducted fairly. Subsequently, rules and guidelines are presented for review by the propulsion community. Additional topics with weighing factors, ranging from 1 to 10 (highest), are welcome. A panel of government experts only, acceptable to the propulsion community, will collect all verbal and written comments and formulate the decisive selection criteria. The final ranking procedure of the topics will not be disclosed. Every organization can participate in this competition and will be subject to the following recommended criteria:

- A government person with a competing CFD program cannot serve on this panel.
- The selected codes and documentation must be available unconditionally.
- The candidate program must execute specific test cases which will be announced by the panel in the future.
- Program application strength to thrust chamber flows will be evaluated.
- Solution accuracy will be assessed.
- Specific simulation features will be appraised.
- User friendliness will be studied.
- Validation status will be reviewed, based on benchmark and sample cases.
- Code competence will be assessed with respect to documented problem results.
- Quality of the program documentation will be surveyed.
- Interaction with other supporting programs, such as preprocessor, grid generator, and postprocessor, including graphics display will be checked.
- Computer oriented topics will be rated (program size, vectorized, etc.)
- Background, experience, and skill of the program developer(s) will be reviewed.
- After selection, new developed routines must be announced and distributed on request.
- The selected codes will serve as reference programs. In this capacity the data can be used for comparison with other code results for validation.

SUMMARY

Information, related to the current CFD program capabilities and provided by various organizations, has been compiled and presented. Specific sample cases for thrust chamber flow demonstration capability are recommended to promote code advancements and validation. The analytical potential of a future comprehensive code has been stated, and the anticipated steps leading to the selection of the best interim candidates have been introduced. The communication between a panel of CFD oriented experts and the propulsion community will review the recommended selection criteria and formulate a final set with associated weighing of the topics. The selection process is projected to occur in the 1992/93 time period.

ACKNOWLEDGEMENT

I wish to acknowledge the support and assistance of Dr. Sura Kim from SVERDRUP, Inc.(Support Contractor to MSFC) during the many discussions leading to the evaluation matrix format, the evaluation of the submitted material, and the typing of the entire table. My thanks also go to Dr. Don Bai and Mr. Huu Trinh, both from MSFC, for their enduring and spirited contribution in this matter.

APPENDIX

ACUREX	Acurex Corporation
AEROJET	Aerojet TechSystems Company
ARGONNE	Argonne National Laboratory
CHAM	CHAM of North America, Inc.
CFDRC	CFD Research Corporation
CREAREX	Creare.X
HSC	Huntsville Sciences Corporation
NASA/ARC	NASA, Ames Research Center
PRI	Physical Research, Inc.
P&W	Pratt & Whitney
REMTECH	Remtech, Inc.
ROCKETDYNE	Rocketdyne
SEA	Software and Engineering Associates
SECA	Software Engineers, Consultants, Analysts
SRA	Scientific Research Associates, Inc.
UAH	University of Alabama, Huntsville
UCI	University of California, Irvine
UIC	University of Illinois, Chicago
UTSI	University of Tennessee, Space Institute

TABLE 3. SAMPLE CASES

- Thrust chamber using O_2/H_2, O_2/C_mH_n propellants
- Combustion chamber equipped with a turbulence ring
- Thrust chamber with tangential flow injection in axial direction
- Combustion chamber with flow injection in circumferential direction
- Thrust chamber with a striated mixture ratio profile
- Thrust chamber with separated nozzle flow
- Thrust chamber with sharp throat radii of curvature
- Combustion chamber with unconventional geometry (inclined injector face, tapered walls, small contraction ratio)
- Combustion chamber with various types of injection patterns
- Thrust chamber with heat transfer to the wall for a given temperature profile
- Thrust chamber with regenerative coolant flow
- Thrust chamber with transpiration cooling
- Time dependent thrust chamber start and shut-down operation

TABLE 1. QUESTIONNAIRE RESULTS

Table 1 (1a)

ORGANIZATION		ACUREX	AEROJET	ARGONNE**	CFDRC	CHAM
RESPONS. PERSON		A. Murray	T. Nguyen	G. Berry	S.Habchi/A.Przekwas	Mahaffey/Vlachos
CODE NAME		KIVA-G	BICOMB	GEMCHIP	REFLEQS	PHOENICS
DIMENSIONS		3D	2D,Axisymmetric	2D	2D,3D	1D,2D,3D
COORDINATES	CART/CYL/SPH/BODY FIT	Cart,BdyFit	BdyFit		BdyFit(all)	Cart,Cyl,BdyFit
TIME PROBLEM	STEADY/UNSTEADY	Unstdy	Stdy	Unstdy	Stdy,Unstdy	Stdy,Unstdy
TYPE OF FLOW	INVISCID/VISCID	Vis(L/T)	Vis(-/T)	Vis(-/T)	Invis,Vis(-/T)	Invis,Vis(L/T)
	INCOMP/COMPRESSIBLE	Incmp,Cmp(all)	Cmp(sb/Tr)	Incmp,Cmp(Sb)	Incmp,Cmp(Sb/Tr/Sp	Incmp,Cmp(Sb/Tr/S
EQUATIONS	CONSERV/NONCONSERV	Consv			Consv	Consv
	MOMENTUM	N-S(Incmp/Cmp)	N-S(Cmp)		N-S	N-S
	ENERGY	Yes	Yes	Yes	Yes	Yes
	SPECIES	Yes(?)	Yes(3 max)	Yes(?)	Yes(4 step reaction)	Yes(35+)
	MULTI PHASES TRACKING	E-L	E-E	E-E	E-L	E-E,E-L(opt)
	EQUATION OF STATE	R.G.(Eqn)	I.G.	I.G.,R.G(Eqn)	R.G.(?)	I.G.,R.G.(?)
	TRANSPORT PROPERTIES	Eqn	Eqn	Eqn	Tabl,Eqn	Tabl,Eqn
PHYSICAL PROCESS	TURBULENCE MODELING	K			B-L(TBD)	MixL
			KeH	KeH	KeH,KeL	KeH
	ATOMIZATION MODEL	Calcu	Assmd(Input)	Assmd	Assmd,Calcu	
	VAPORIZATION MODEL	Drplet(M)	Yes(?)	Yes(?)	Drplet(S/M)	Crit(Sup)
	CHEMISTRY MODEL	FR	FR	FR	EQ,FR	EQ,FR
	RADIATION MODEL	-			Yes(6 flux eqn)	6 Flux Model
ROCKET PROPELLANT	TYPE	General(?)	all		HC/Air,Hypergolic	Hc/Air,O2
	PHASES(FUEL/OX)	Multi(G/L)	Two(G/G,G/L)	Two(L/G,L/L)	Sgl,T(G/G,G/L,L/L)	Two(?)
DISCRETIZATION	FDM/FVM/FEM/SPECTRAL/ETC.	FVM	FVM	FVM	FVM	FVM
NUMERICAL SCHEME	VARIABLES BASED	P-V		P-V	P-V	P-V
	DIFF. ACCURACY:TIME/SPATIAL	T(1st)/S(1st,2nd)	T(?)/S(2nd)		T(1st)/S(1st,2nd)	T(?)/S(1st,2nd)
	MULTI STEP/FACTORIZATION	-				MS(No)/FACT(Yes)
	EXPLICIT	Explicit(Temporal)				No
	IMPLICIT	Implicit(Spatial)		Fully Implicit	Fully Implicit	Implicit
	OTHERS: SPECIFY	ALE			TVD	
			SIMPLER	SIMPLER	SIMPLEC	SIMPLEST,IPSA
	MULTIGRID CAPABILITY	No			No	No
MATRIX SOLVER	DIRECT METHOD	Not Req'd	TDMA	TDMA	Mod. Stone's solver	Stone's solvr
	ITERATIVE METHOD		Line Iter	Line Iter		

Survey Date : October, 1990 (Except **)

TABLE 1. QUESTIONNAIRE RESULTS

Table 1 (1b)

ORGANIZATION		ACUREX	AEROJET	ARGONNE**	CFDRC	CHAM
RESPONS. PERSON		A. Murray	T. Nguyen	G. Berry	S.Habchi/A.Przekwas	Mahaffey/Vlachos
CODE NAME		KIVA-G	BICOMB	GEMCHIP	REFLEQS	PHOENICS
GRID	SEPARATE (NAME)	GGP			EAGLE,GGP(opt)	GGP,Others
	INTERNAL	Northo	Stgg,Northo	Ortho	Ortho/Northo	Stgg,Ortho/Northo
			Strct	Adapt	Strct	Strct
	TECHNIC USED	N/A	Algbr		Algbr	Algbr,Diff
INLET/WALL	INLET CONDITIONS	Const	Const.		Const,TimeVar	Const,TimeVar
BOUNDARY COND.	WALL BOUNDARY	Usr specify	Nslp	Nslp	Usr Select.	Slp/Nslp,MV/Fix
		Adiab,Isoth	Adiab	Adiab		Adiab,Isoth,Flux
		Surf(S)	Surf(S)	Handl Interior B.C.	Handl Interior B.C.	Handl Interior B.C.
		Adh			Adh,Bounce	
PROGRAM CAPABILIT	INCOMPRESSIBLE FLOWS				Swirl, Rotation flow	All
(Experienced)	COMPRESSIBLE FLOWS	0.1 - 24	0.1 - 20		0 - 65	All
	INTERNAL FLOW	Recirc,Cavity	Separ,Recirc		Separ,Recirc,Cavity	All
		Combustor,Nozz	Combustor,Nozz	Spray combustion	Combustor,Nozz	Combustor,Nozz
	INJECTION	Coaxial			Yes(?)	
		Atom,Vapor	Mix,Vapor		Atomiz,Vapor,Mix	
	PERFORMANCE PREDICTION	Therm,Dyn Prop	All	Therm,Dyn prop	Thrust,Isp,Dyn prop	All
	MISC.	Plume,Shock tube			Duct	Duct
CODE VALIDATION	UNIQUE CASES	13			40	~ 200
	CASES PUBLISHED	7			30	~ 25
	THRUST CHMBR RELATED	5			4	~ 5
PRE/POST PROCESSOR	DEVELOPED	Inhouse	Inhouse	N/A	Inhouse	Inhouse,Others
	OPERATION	Batch	Batch,Interact		Batch,Interact	Interact
	GRAPHICS	DI300,DISSPLA	DI3000,Plot3D	N/A	Plot3D,XYPLOT	Self,PATRAN,Sprta
PROGRAM	DOCUMENTATION	Eng,User	N/A(TBD)	TBD	Eng,Prog,User	Eng,Prog,User
	AVAILABILITY	Prop	Prop	Pub(Argonne)	Prot	Sale
COMPUTER SYSTEM	MAIN FRAME	Cray	Cray	Cray,IBM	Cray,IBM	Cray,IBM,Cyb
	MINI COMPUTER	Vax	Vax	Vax	Alliant,Ardent,Vax	Convex,Alliant,Vax
	WORKSTATION		SG		Sun	Sun,Apollo,Tek
MISCELLANEOUS	CODE EXPERIENCE	2 Yrs	1 Yrs	4 Yrs	4 Yrs	9 Yrs
	CODE ORIGIN	Acq(KIVA)	Acq(GEMCHIP)	Inhouse	Inhouse	Inhouse
	VECTORIZATION	Yes	No		Yes	Yes

Survey Date : October, 1990 (Except **)

TABLE 1. QUESTIONNAIRE RESULTS

Table 1 (2a)

ORGANIZATION		CREARE.X	CREARE.X	CREARE.X	HSC	NASA,ARC
RESPONS. PERSON		Z. Sheikh	S. Subbiah	S. Subbiah	L. Spradley	S. Yoon/D. Kwak
CODE NAME		FLUENT	RAMPANT	NEKTON	PACES	CENS3D
DIMENSIONS		2D,3D	2D,3D	2D,3D	2D,3D	2D,3D
COORDINATES	CART/CYL/SPH/BODY FIT	Cart,Cyl,BdyFit	BdyFit	BdyFit	BdyFit	BdyFit
TIME PROBLEM	STEADY/UNSTEADY	Stdy,Unstdy	Stdy,Unstdy	Unstdy	Unstdy	Stdy,Unstdy
TYPE OF FLOW	INVISCID/VISCID	Invis,Vis(L/T)	Invis,Vis(L/T)	Invis,Vis(L)	Invis,Vis(L/T)	Invis,Vis(L/T)
	INCOMP/COMPRESSIBLE	Incmp,Cmp(Sb/Tr/Sp	Cmp(Sb/Tr/Sp)	Incmp	Cmp(?)	Cmp(all)
EQUATIONS	CONSERV/NONCONSERV	Consv	Consv	NonConsv	Consv	Consv
	MOMENTUM	N-S	N-S,Eul	N-S	N-S(Cmp)	N-S(-/Cmp)
	ENERGY	Yes	Yes	Yes	Yes	
	SPECIES	Yes(unlimit)		No	Yes(30)	Yes(11)
	MULTI PHASES TRACKING	E-L				
	EQUATION OF STATE	I.G.	I.G.		I.G.,R.G.(Tabl)	R.G.(Eqn)
	TRANSPORT PROPERTIES	Tabl,Eqn		Eqn	Eqn	Eqn
PHYSICAL PROCESS	TURBULENCE MODELING					B-L
		KeH	KeH		KeH/KeL	
		AST,RSM				
	ATOMIZATION MODEL	Assmd				
	VAPORIZATION MODEL	Drplet(S/M)				
	CHEMISTRY MODEL	EQ,FR			FR	FR
	RADIATION MODEL	Discrete Trans				
ROCKET PROPELLANT	TYPE				H2/O2,HC/Air	Air/H2
	PHASES(FUEL/OX)	Sngl(S/G)			Sngl	
DISCRETIZATION	FDM/FVM/FEM/SPECTRAL/ETC.	FVM	FVM	Spectral	FEM	FVM
NUMERICAL SCHEME	VARIABLES BASED	P-V	D-V	P-V	D-V	D-V
	DIFF. ACCURACY:TIME/SPATIAL	T(1st)/S(1st)	T(1st)/S(2nd)	T(3rd)/S(15th)	T(2nd)/S(2nd)	T(1st)/S(2nd)
	MULTI STEP/FACTORIZATION	MS(No)/FACT(No)			MS(Yes)/FACT(No)	MS(No)/FACT(Yes)
	EXPLICIT			Adam-Baschworth	FEM-FCT	
	IMPLICIT					Yoon-Jameson
	OTHERS: SPECIFY				ALE,Tay-Gal,FCT	TVD
		SIMPLE				
	MULTIGRID CAPABILITY	No		Yes	No	Yes
MATRIX SOLVER	DIRECT METHOD	TDMA		Tensor Product		
	ITERATIVE METHOD	Iter		CGM	Iter	G-S(LU-SGS)

Survey Date : October, 1990 (Except **)

TABLE 1. QUESTIONNAIRE RESULTS

Table 1 (2b)

ORGANIZATION		CREARE.X	CREARE.X	CREARE.X	HSC	NASA,ARC
RESPONS. PERSON		Z. Sheikh	S. Subbiah	S. Subbiah	L. Spradley	S. Yoon/D. Kwak
CODE NAME		FLUENT	RAMPANT	NEKTON	PACES	CENS3D
GRID	SEPARATE (NAME)	PREFL	PREFL	PRENEK		GGP
	INTERNAL	Stgg,Northo	Nstgg,Northo	Nstgg,Northo		Ortho/Northo
		Strct	Unstrct,Adpt	Unstrct	Unstrc,Adapt	Adapt,MultZon
	TECHNIC USED	Algbr,Diff	Algbr	FEM	FEM	Algbr,Diff
INLET/WALL	INLET CONDITIONS	Const,TimeVar	Const	Const,TimeVar	Const,TimVar,Char	Const,TimeVar
BOUNDARY COND.	WALL BOUNDARY	Slp/Nslp,MV/Fix	Slp/Nslp,MV/Fix	Slp/Nslp,MV/Fix	Nslp,Mv	Nslp
		Adiab,Isoth,Flux	Adiab,Isoth,Flux	Adiab,Isoth,Flux	Isoth	Nonreflecting cond
		Surf(S/R)	Surf(S)	Surf(S)	Surf(S)	
		Adh,Bounce,Salta(?)				
PROGRAM CAPABILIT	INCOMPRESSIBLE FLOWS	0.1 - 1.0E12		Laminar-Trans	1.0E2 - 1.0E8	
(Experienced)	COMPRESSIBLE FLOWS	0.1 - 5.0	0.3 - 5.0	< 0.3		0.1-30
	INTERNAL FLOW	Recirc,Separ	Separ,Recirc	Separ,Recirc	Separ,Recirc	Separ
		Combustor,Nozz			Combustor,Nozz	Inlet/Combustor
	INJECTION	Coax,Impinge				
		Vapor,Mix				
	PERFORMANCE PREDICTION				Therm,DynProp,Isp	Therm,Dyn Prop
	MISC.				WaveImpinge,Aero	Hypersonic Vehicle
CODE VALIDATION	UNIQUE CASES	250			10	
	CASES PUBLISHED	30			25	
	THRUST CHMBR RELATED				2	
PRE/POST PROCESSOR	DEVELOPED	Inhouse	Inhouse	Nektonics	Inhouse,Others	Inhouse
	OPERATION	Batch,Intract	Batch,Intract	Batch,Interact	Batch,Interact	Interact
	GRAPHICS	Self	Self	Self	Self,SG-IRIS	GAS,SURF,Plot3D
PROGRAM	DOCUMENTATION	Eng,Prog,User	Eng,Prog,User	Eng,Prog,User	N/A	
	AVAILABILITY	Sale	Sale,Prop	Sale	SBIR	Pub
COMPUTER SYSTEM	MAIN FRAME	Cray,IBM	Cray,IBM	Cray,IBM	Cray,Cyb	Cray
	MINI COMPUTER	Convex,Alliant,Vax	Convex,Alliant,Vax	Convex,Alliant	Vax,Convex	Vax
	WORKSTATION	Sun,Apollo,Tek	Sun,Tek	Sun,Apollo,Tek	SG,UNIX	SG
MISCELLANEOUS	CODE EXPERIENCE	8 Yrs	1 Yrs	4 Yrs	3 Yrs	2 Yrs
	CODE ORIGIN	Inhouse	Inhouse	Acq(MIT)	Acq(PEFLO)	Inhouse
	VECTORIZATION	No	No	Yes	Yes	Yes

Survey Date : October, 1990 (Except **)

TABLE 1. QUESTIONNAIRE RESULTS

Table 1 (3a)

ORGANIZATION		P & W	P & W	PRI	PRI	REMTECH
RESPONS. PERSON		D. Hill	C. Rhie	Dang/Kehtamavaz	Dang/Kehtamavaz	S.Praharaj/P. Liver
CODE NAME		ARICC	NASTAR	NSI	UPNS	PARCREM
DIMENSIONS		2D,Axisymmetric	2D,3D	2D	2D	2D,3D
COORDINATES	CART/CYL/SPH/BODY FIT		BdyFit	BdyFit	BdyFit	BdyFit
TIME PROBLEM	STEADY/UNSTEADY	Unstdy	Stdy	Unstdy	Stdy	Stdy,Unstdy
TYPE OF FLOW	INVISCID/VISCID	Invis,Vis(L/T)	Invis,Vis(L/T)	Vis(-/T)	Vis(-/T)	Invis,Vis(L/T)
	INCOMP/COMPRESSIBLE	Cmp(Sb)	Incmp,Cmp(all)	Cmp(?)	Cmp(?)	Cmp(all)
EQUATIONS	CONSERV/NONCONSERV	Consv	Consv			Consv
	MOMENTUM	N-S	N-S,PNS,Eul	N-S(Cmp)	PNS	NS(Cmp),TLNS,Eul
	ENERGY	Yes	Yes	Yes	Yes	Yes
	SPECIES	Yes(11 max)	Yes(4,5,7)		Yes(40)	Yes(9)
	MULTI PHASES TRACKING	E-L				
	EQUATION OF STATE	I.G.	I.G.,R.G.(Tabl)	I.G.	I.G.,R.G.(Cp=C)	I.G.,R.G.(Eqn)
	TRANSPORT PROPERTIES	Eqn	Tabl,Eqn		Tabl	Eqn
PHYSICAL PROCESS	TURBULENCE MODELING	MixL(SGS)	B-L	Cebeci-Smith	Cebeci-Smith	B-L
		KeH	KeH,KeL		KeH	KeL
	ATOMIZATION MODEL	Assmd				
	VAPORIZATION MODEL	Drplet(S/M)				
	CHEMISTRY MODEL	EQ,FR	FR		FR	EQ
	RADIATION MODEL			No		
ROCKET PROPELLANT	TYPE	H2/O2	H2/O2,HC			H2/O2
	PHASES(FUEL/OX)	Two(G/L)			Sngl	Sngl(gas)
DISCRETIZATION	FDM/FVM/FEM/SPECTRAL/ETC.	FVM	FVM	FDM	FDM	FDM
NUMERICAL SCHEME	VARIABLES BASED	P-V	P-V	D-V	D-V	D-V
	DIFF. ACCURACY:TIME/SPATIAL	T(1st)/S(1st)	T(?)/S(2nd)	T(?)/S(2nd)	T(?)/S(2nd)	T(2nd)/S(2nd)
	MULTI STEP/FACTORIZATION		MS(Yes)/FACT(No)			MS(Yes)/FACT(Yes
	EXPLICIT					
	IMPLICIT	Implicit	Implicit			B-W
	OTHERS: SPECIFY	ALE		TVD	TVD	ADI
			PISO			
	MULTIGRID CAPABILITY	No	Yes			No
MATRIX SOLVER	DIRECT METHOD		SLOR TDMA	BTDMA	BTDMA	Pentadiagonal Slvr
	ITERATIVE METHOD	Point solver-?	Iter			

Survey Date : October, 1990 (Except **)

TABLE 1. QUESTIONNAIRE RESULTS

Table 1 (3b)

ORGANIZATION		P & W	P & W	PRI	PRI	REMTECH
RESPONS. PERSON		D. Hill	C. Rhie	Dang/Kehtamavaz	Dang/Kehtamavaz	S.Praharaj/P. Liver
CODE NAME		ARICC	NASTAR	NSI	UPNS	PARCREM
GRID	SEPARATE (NAME)		GGP			INGRID
	INTERNAL	Stgg,Northo	Nstgg,Northo			
			Strct,MultZone			Strct,Adp,MultZon
	TECHNIC USED	Algbr	FEM,Algbr,Diff	Algbr	Algbr	Algbr
INLET/WALL	INLET CONDITIONS	Const	Const.			Const,TimeVar
BOUNDARY COND.	WALL BOUNDARY	Nslp	All		Nslp	Nslp,MV
		Isoth	All			Adiab,Isoth
		Surf(S)	Surf(S)			Surf(S)
		Bounce				-
PROGRAM CAPABILIT	INCOMPRESSIBLE FLOWS		1.0E0 - 1.0E8			1.0E2 - 1.0E8
(Experienced)	COMPRESSIBLE FLOWS		0.0 - 30			0.4 - 33
	INTERNAL FLOW		All			Separ,Recirc,Cavity
			Combustor,Nozz	Nozz	Combustor,Nozz	Nozz
	INJECTION	Coax	All			-
		Atomiz,Vapor,Mix				-
	PERFORMANCE PREDICTION	Dyn Prop		All	All	Therm,Dyn prop
	MISC.					Ext flow,Plume
CODE VALIDATION	UNIQUE CASES	8	300			> 20
	CASES PUBLISHED	4	30			> 10
	THRUST CHMBR RELATED	-	100			5
PRE/POST PROCESSOR	DEVELOPED	Inhouse(Post)	Inhouse,Others	N/A	N/A	Inhouse
	OPERATION	Batch	Batch			Batch,Interact
	GRAPHICS	Plot3D,Self	Plot3D,Self	Calcomp	Calcomp	Plot3D,DISSPLA
PROGRAM	DOCUMENTATION	Usr	User	N/A	Eng,User	Eng,User
	AVAILABILITY	Pub-MSFC	Prop	Pub	Pub(TBD)	Pub,Prop(some)
COMPUTER SYSTEM	MAIN FRAME	Cray	Cray			Cray
	MINI COMPUTER			Vax	Vax	Convx,Multiflow
	WORKSTATION			Sun	Sun	Sun
MISCELLANEOUS	CODE EXPERIENCE	2 Yrs	6 Yrs	1 Yrs	1.5Yrs	4 Yrs
	CODE ORIGIN	Acq(ARICC)	Inhouse	Inhouse	Inhouse	Acq(PARC)
	VECTORIZATION	Yes(Parts)	Yes			Partially

Survey Date : October, 1990 (Except **)

TABLE 1. QUESTIONNAIRE RESULTS

Table 1 (4a)

ORGANIZATION		ROCKETDYNE	SEA	SECA	SRA	UAH
RESPONS. PERSON		P.Y. Liang	D. Coats	Y. Chen	J. Sabnis	C.P. Chen
CODE NAME		ARICC3D	VIPER	FDNS	CELMINT	MAST
DIMENSIONS		2D,3D	2D	2D,3D	2D,3D	
COORDINATES	CART/CYL/SPH/BODY FIT	BdyFit	BdyFit	BdyFit	BdyFit	BdyFit
TIME PROBLEM	STEADY/UNSTEADY	Unstdy	Stdy	Stdy,Unstdy	Stdy(opt),Unstdy	Unstdy
TYPE OF FLOW	INVISCID/VISCID	Vis(-/T)	Invis,Vis(L/T)	Invis,Vis(L/T)	Vis(-/T)	Invis,Vis(-/T)
	INCOMP/COMPRESSIBLE	Cmp(?)	Cmp(?)	Incmp,Cmp(Sb/Tr/Sp	Incmp(opt),Cmp(?)	Incmp,Cmp(?)
EQUATIONS	CONSERV/NONCONSERV		Consv	Consv	Consv	Consv
	MOMENTUM	N-S(-/Cmp)	PNS	N-S(Incmp/Cmp)	N-S(-/Cmp)	NS(Incmp/Cmp),Eul
	ENERGY	Yes	Yes	Yes	Yes	Yes
	SPECIES	Yes(?)	Yes(40)	Yes(compt. memory)	Yes(?)	Yes(?)
	MULTI PHASES TRACKING	E-L	-	E-E,E-L	E-E,E-L	E-L,Stat
	EQUATION OF STATE	I.G.,R.G.(Cp=C)	R.G.(?)	R.G.(Eqn)	I.G.,R.G.(Tabl)	I.G.,R.G.(Eqn)
	TRANSPORT PROPERTIES	Eqn	Eqn	Tabl,Eqn	Eqn	Eqn
PHYSICAL PROCESS	TURBULENCE MODELING	SGS	Cebeci-Smith		MixL	
		KeH,2-Scale	KeH	KeH,KeL	KeL	KeH,KeL
				ASM		Multi-Scale Model
	ATOMIZATION MODEL	Yes		Assmd		Assmd
	VAPORIZATION MODEL	Yes		Drplet(S/M)	Drplet(S)	Drplt(S/M),Crit(Sb)
	CHEMISTRY MODEL	EQ,FR	EQ,FR	EQ,FR	FR,Statistic. Model	EQ
	RADIATION MODEL			Yes(?)		-
ROCKET PROPELLANT	TYPE	H2/O2,HC/O2	All	H2/O2,HC/O2,Other		H2/O2
	PHASES(FUEL/OX)	Two(G/L)	(1) Sngl,Two	Two(G/G,G/L,G/S)	Sngl,Two(G/L,G/S)	Two(G/S,G/L)
DISCRETIZATION	FDM/FVM/FEM/SPECTRAL/ETC.	FVM	FDM	FDM	FDM,FVM	FVM
NUMERICAL SCHEME	VARIABLES BASED			P-V	D-V	P-V
	DIFF. ACCURACY:TIME/SPATIAL	T(1st)/S(1st,2nd)	S(2nd)	T(2nd)/S(4th)w/ Diss	T(1st,2nd)/S(2nd)	T(2nd)/S(2nd)
	MULTI STEP/FACTORIZATION	MS(Yes)/FACT(No)		MS(Yes)/FACT(No)	MS(No)/FACT(Yes)	MS(Yes)/FACT(No)
	EXPLICIT					
	IMPLICIT	Implicit	B-W	Time-Centered	B-McD	
	OTHERS: SPECIFY	ALE		C-N,TVD	Block ADI	
		SOLA-VOF		Multi-Correctors		PISOC
	MULTIGRID CAPABILITY	No	No	Yes	No	Yes
MATRIX SOLVER	DIRECT METHOD		TDMA	Stone's solvr	BTDMA	
	ITERATIVE METHOD	CRM		or Line Iter.		CGM(CGS)

Survey Date : October, 1990 (Except **)

(1) Equil. gas particle mixture

TABLE 1. QUESTIONNAIRE RESULTS

Table 1 (4b)

ORGANIZATION		ROCKETDYNE	SEA	SECA	SRA	UAH
RESPONS. PERSON		P.Y. Liang	D. Costs	Y. Chen	J. Sabnis	C.P. Chen
CODE NAME		ARICC3D	VIPER	FDNS	CELMINT	MAST
GRID	SEPARATE (NAME)	GGP		EAGLE,GENIE,GR	EAGLE,GGP	
	INTERNAL	Stgg,Northo		Nstgg,Northo	Northo,Moving	Northo
		Strct,Adp	Strct	Unstrc,MultZone	Adapt,MultZon	
	TECHNIC USED	Algbr	Algbr	Algbr,Diff		Diff
INLET/WALL	INLET CONDITIONS	Usr Specify	Const	Const,TimeVar	Const,TimeVar	Const,TimeVar
BOUNDARY COND.	WALL BOUNDARY	Usr Specify	Nslp	Slp/Nslp	Usr specify	Nslp,MV
			Adiab,Flux	Adiab,Isoth,Flux		Const,TimeVar
			Surf(S)	Surf(S)	Handl Interior B.C.	Surf(S)
				Adh,Bounce	Adh,Bounce	Adh,Bounce
PROGRAM CAPABILIT	INCOMPRESSIBLE FLOWS		1.0E3 - 1.0E7	0.1 - ∞	1.0-1.0E7	1.0E1 - 1.0E6
(Experienced)	COMPRESSIBLE FLOWS	0 - 6	1.0 - 10	0.0 - 20	1.0E-4 - 20	0.1 - 8
	INTERNAL FLOW	Separ,Recirc,Cavity		Recirc,Cavity,Separ	Ballistic,Cavity	Separ,Recirc,Cavity
		Combustor,Nozz	Nozz	Combustor,Nozz	RocketMotor,Nozz	
	INJECTION	Coax,Transverse		Coax		Coax
		Atomiz,Vapor,Mix			Vapor,Mix	Vap,Mix
	PERFORMANCE PREDICTION	Therm Prop	All	All	Therm,Dyn Prop	
	MISC.	Pipe flow,BwdStep		Duct,Turblad,Plum	Ext flow(tr/Hyper)	
CODE VALIDATION	UNIQUE CASES		8	46	40	15
	CASES PUBLISHED		8	29	25	10
	THRUST CHMBR RELATED		8	7		0
PRE/POST PROCESSOR	DEVELOPED	Inhouse/Others	Inhouse,Post	Inhouse	Others	Inhouse
	OPERATION	Batch(?)	Batch	Batch	Batch,Interact	Batch
	GRAPHICS	DISSPLA,Self	Self	Self,Plot3D	Plot3D	Display
PROGRAM	DOCUMENTATION	Usr(2D only)	Eng,User	User	Eng,Prog,User	Eng,Prog
	AVAILABILITY	Prot	Pub	Pub	Prop,Sale,Prot,Pub	Pub
COMPUTER SYSTEM	MAIN FRAME	Cray		Cray,IBM	Cray,Cyb	Cray
	MINI COMPUTER	FPS	Vax	Aviion	Vax	
	WORKSTATION	Sun	Sun		Sun,SG	Sun
MISCELLANEOUS	CODE EXPERIENCE	1 Yrs	Developing	4 Yrs	14 Yrs	Developing
	CODE ORIGIN	Acq(KIVAII,ARICC	Inhouse	Inhouse	Inhouse	Inhouse
	VECTORIZATION	Yes	No	Partially	Yes	No

Survey Date : October, 1990 (Except **)

TABLE 1. QUESTIONNAIRE RESULTS

Table 1 (5a)

ORGANIZATION		UCI	UIC**	UTSI	UTSI**	RCKTDYNE
RESPONS. PERSON		R. Rangel	P. Chiu	S. Jeng	F. Collins	M. Sindir
CODE NAME		SHEET2	GEMCHIP I,II,III	ABC(KIVA-II)	CASP(PARC)	USA
DIMENSIONS		2D	3D	3D	2D,Axisymmetric	
COORDINATES	CART/CYL/SPH/BODY FIT	Cart		BdyFit	BdyFit	
TIME PROBLEM	STEADY/UNSTEADY	Unstdy	Stdy,Unstdy	Unstdy	Stdy	Unstdy
TYPE OF FLOW	INVISCID/VISCID	Invis	Vis(-/T)	Vis(L/T)		Invis,Vis(-/T)
	INCOMP/COMPRESSIBLE	Incmp	Cmp(?)	Cmp(Sb)		Incmp,Cmp(all)
EQUATIONS	CONSERV/NONCONSERV			Consv	Consv	
	MOMENTUM	N-S(Incmp)-Vorti	N-S(Cmp)	N-S(Cmp)	N-S(Cmp),Eul	N-S(Incmp/Cmp)
	ENERGY	(1).		Yes		
	SPECIES	Yes(4)	Yes(?)	Yes(30)		
	MULTI PHASES TRACKING	E-L	E-E	E-L		
	EQUATION OF STATE	I.G.	I.G.,R.G.(?)	R.G.(Eqn)	I.G.	R.G(Eqn)
	TRANSPORT PROPERTIES	Eqn		Eqn	Eqn	Eqn
PHYSICAL PROCESS	TURBULENCE MODELING				B-L	B-L,K
		LES	Modified KeH	KeH		KeH
	ATOMIZATION MODEL	Assmd	Assmd	Assmd		
	VAPORIZATION MODEL	Drplet(S/M)	(1),(2) Drplet(?)	Crit(Sub/Sup)		
	CHEMISTRY MODEL	TBD	FR	EQ,FR	EQ	FR
	RADIATION MODEL	TBD	TBD			
ROCKET PROPELLANT	TYPE	HC		MMH/N2O2	H2/O2	
	PHASES(FUEL/OX)	Two(?)	Multi(G/G,L/G,L-L/G	Two(L/L)	Sngl	
DISCRETIZATION	FDM/FVM/FEM/SPECTRAL/ETC.	FDM-Scalar	FVM	FVM	FVM	FVM
NUMERICAL SCHEME	VARIABLES BASED	Lagrangian manner		P-V		
	DIFF. ACCURACY:TIME/SPATIAL	2nd Runge-Kutta	T(-)/S(1st)	T(1st)/S(2nd)	T(-)/S(2nd)	
	MULTI STEP/FACTORIZATION				MS(No)/FACT(Yes)	MS(Yes)/FACT(Yes
	EXPLICIT	Explicit				Explicit(R-K)
	IMPLICIT		Fully implicit		B-W	Implicit
	OTHERS: SPECIFY			ALE		TVD/Riemann
			SIMPLER			
	MULTIGRID CAPABILITY	No		No		
MATRIX SOLVER	DIRECT METHOD	TDMA	TDMA		Pentadiagonal solvr	TDMA,BTDMA
	ITERATIVE METHOD		Line Iter	CGM		

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(1) Vorticity field eq' (1) Droplet dispersion model

(2) Group/Conjugate effects included

TABLE 1. QUESTIONNAIRE RESULTS

Table 1 (5b)

ORGANIZATION		UCI	UIC**	UTSI	UTSI**	RCKTDYNE
RESPONS. PERSON		R. Rangel	P. Chiu	S. Jeng	F. Collins	M. Sindir
CODE NAME		SHEET2	GEMCHIP I,II,III	ABC(KIVA-II)	CASP(PARC)	USA
GRID	SEPARATE (NAME)	Cartesian(?)	Preselected grid		INGRID	Northo
	INTERNAL		Ortho	Ortho/Northo		Strc,MultZone
				Adapt(TBD)		
	TECHNIC USED			Diff		
INLET/WALL	INLET CONDITIONS	Must be assumed		Const	Usr specify	Usr Specify
BOUNDARY COND.	WALL BOUNDARY		Fix	Slp/Nslp	Need start file	
		No Walls	Adiab,Flux	Adiab,Isoth,Flux		
		Handl Periodic B.C.		Surf(S/R)		
				Adh,Bounce		
PROGRAM CAPABILIT	INCOMPRESSIBLE FLOWS	1.0E1 - 1.0E2				
(Experienced)	COMPRESSIBLE FLOWS			0.1-1.2	-33	
	INTERNAL FLOW					Cavity
			Combustor	Rocket		Combustor,Nozz
	INJECTION				Nozz	
		Vapor,Mix				
	PERFORMANCE PREDICTION	Vorticity,Velocity	Therm,Dyn Prop	Therm		Therm,Dyn Prop
	MISC.				Ext.flow,Duct,etc	Ext.flow(Sup,Hyp)
CODE VALIDATION	UNIQUE CASES	5		5		
	CASES PUBLISHED	5		2		
	THRUST CHMBR RELATED			2		
PRE/POST PROCESSOR	DEVELOPED	Inhouse	Others	N/A	Others	Inhouse
	OPERATION		Batch	Batch		Interact
	GRAPHICS	GPR,Self		Plot3D	Plot3D	Self
PROGRAM	DOCUMENTATION	N/A	TBD	N/A		Usr
	AVAILABILITY		Prop,Pub	Prop		Prop
COMPUTER SYSTEM	MAIN FRAME		Cray		Cray	Cray,Cyb
	MINI COMPUTER			Alliant	Multiflow	Convex
	WORKSTATION	Apollo	Sun		Sun	Sun
MISCELLANEOUS	CODE EXPERIENCE	2 Yrs	6/4/2 Yrs	1 Yrs	3 Yrs	4 Yrs
	CODE ORIGIN	Inhouse	Inhouse	Acq(KIVA II)	Acq(PARC)	Inhouse
	VECTORIZATION	No		Yes		

Survey Date : October, 1990 (Except **)

TABLE 2. ABBREVIATIONS

COORDINATES	CART,CYLIN,SPHER,BODY FIT		Cart,Cyl,Sph,BdyFit
TIME PROBLEM	STEADY/UNSTEADY		Stdy,Unstdy
TYPE OF FLOW	INVISCID/VISCID	Inviscid,Viscid(Laminar/Turbulent)	Invis,Vis(L/T)
	INCOMPRESSIBLE/COMPRESSIBL	Incopm,Comp(Subsonic/Transonic/Supersonic/Hypersonic)	Incmp,Cmp(Sb/Tr/Sp/Hp)
EQUATIONS	CONSERV/NONCONSERV FORM		Consv,Nconsv
	MOMENTUM/ENERGY/SPECIES	N-S(Incomp/Comp),PNS,Euler// Energy(Max. Number of species)	N-S(Incmp/Cmp),PNS/--/Yes(9)
	MULTI PHASES TRACKING	Eul-Eul,Eul-Lag,Statistic	E-E,E-L,Stat
	EQUATION OF STATE	Ideal,Real Gas((Table/Equation)	I.G.,R.G.(Tabl/Eqn)
	TRANSPORT PROPERTIES	Table,Equation	Tabl,Eqn
PHYSICAL PROCESS	TURBULENCE MODELING	Zero(Mixing Length/Baldwin-Lomax),1-BQ,2-BQ(K-l,KEHigh,	MixL,B-L,K,K-l,KeH,
		,KELow,etc.),LES,PDF,Algebraic Stress Model,Reynolds Stress Model	KeL,LES,PDF,ASM,RSM
	ATOMIZATION MODEL	Drop Size(Assumed/Calculated),Vorticity,Others	Assmd,Calcu,Vorti
	VAPORIZATION MODEL	Droplet(Single/Multi),Critical Region(Subsonic/Supersonic)	Drplet(S/M),Crit(Sub/Sup)
	CHEMISTRY MODEL	None,Equilibrium,Finite Rate,etc.	No,EQ,FR
	RADIATION MODEL	State Source: Flame,Wall,etc.	Flame,Wall
ROCKET PROPELLANT	TYPE	O2,H2,Hydrocarbon,Hypergolic,etc.	H2/O2,HC/O2
	PHASES(FUEL/OX)	Single,Two Phase(Gas,Liquid,Solid)	Sngl,Two(G/G,G/L,S/G)
DISCRETIZATION	FDM/FVM/FEM/SPECTRAL/ETC	Finite Difference,Finite Volume,Finite Element,Spetral Method	FDM,FVM,FEM,SP
NUMERICAL SCHEME	DIFF. ACCURACY:TIME/SPATIAL	Order of Approx. - Time(1st,2nd)/Spatial(1st,2nd,Higher)	T(1st)/S(2nd)
	MULTI STEP/FACTORIZATION	Multistep Method(Yes,No)/Factorization(Yes,No)	MS(Yes,No)/FACT(Yes,No)
	EXPLICIT	Leapfrog/DuFort-Frankel,Lax-Wendroff,MaCormack,Hopscotch,etc.	L/D-F,L-W,MaC,Hop,etc.
	IMPLICIT	MaCormack,Beam-Warming,Briley-McDonald,etc.	MaC,B-W,B-McD
	OTHERS	Crank-Nicolson,ADI,TVD,ALE/ICE-ALE,Flux Correct Transport,Taylor-Galerki	C-N,ADI,TVD,ALE,FCT,Tay-Gal
		SIMPLE's,PISO's,SOLA-VOF,etc.	SIMP,PISO,SOLA
	VARIABLES BASED	Pressure Based,Density Based, Others	P-V,D-V,Others
	MULTIGRID CAPABILITY	Yes/No	Yes/No
MATRIX SOLVER	DIRECT METHOD	TDMA,Block TDMA,Error Vector Prop.,etc.	TMDA,BTMDA,EVP
	ITERATIVE METHOD	Line Iter.,Gauss-Seidel,SOR,Conjugate Gradient /Residue Method,etc.	Iter,G-S,SOR
GRID	SEPARATE (NAME)	EAGLE,GRID,Grid Generation Package,etc.	EAGLE,GRID,GGP,etc.
	INTERNAL	Stagg/Non-Stagg,Ortho/Non-Ortho,Struct/Unstruct,Adaptive Grids/Multi Zone	Stgg/Nstgg,Ort/Northo,Adp,MltZ
	TECHNIC USED	FEM,Algebraic,Differential Eq'n	FEM,Algbr,Diff
BOUNDARY CONDITIO	INLET/WALL BOUNDARY	Inlet: Constant,Time Varying; Wall: No slip/Slip,Stationary/Moving,	Con,TVar;Slp/Nslp,Mv/Fix
		Adiabatic,Isotherm,Const. Flux,Smooth/Rough Surface,etc.	Adiab,Isoth,Flux,Surf(S/R)
		Droplet wall interaction(Adhere/Bounce/Others)	Adh,Bounce
PROGRAM CAPABILITY	INCOMPRESSIBLE FLOWS	Specify Reynolds No. Ranges	1.0E2 -1.0E8
(Experienced)	COMPRESSIBLE FLOWS	Specify Mach No. Ranges	0.1 - 30
	INTERNAL FLOW	Seperating,Recirculating,Cavity Flows,etc.	Separ,Recirc,Cavity
		Combustion Chamber,Nozzle	Chmbr,Nozz
	INJECTION	Element-Coaxial/Impingement, Process-Atomization/Mixing/Vaporization	Coax,Impinge
	PERFORMANCE PREDICTION	Thrust Chamber:Thrust,Isp,Thermodynamic Properties,Dynamics Properties	Thrust,Isp,Therm,Dyn prop
	MISC.	Other than Thrust Chamber	
CODE VALIDATION	UNIQUE/PUBLISHED CASES	Number of Unique Cases Solved(Include benchmark cases)/No. of Publications	30/7
	THRUST CHAMBER RELATED	Number of Cases related to Thrust Chamber	5
PRE/POST PROCESSORS	DEVELOPED	In-house,By Others	Inhouse/Others
	GRAPHICS	Display,Plot3D,Self,etc.	Display,Plot3D,Self,etc
	OPERATION	Batch,Interactive	Batch,Interact
PROGRAM	DOCUMENTATION	Manual-Engineering,Program,User	Eng,Prog,User
	AVAILABILITY	Proprietary,Sale,Protect(SBIR),Public Domain	Prop,Sale,Prot,Pub
COMPUTER SYSTEM	MAIN FRAME	Cray,IBM,Cyber,etc.	Cray,IBM,Cyber
	MINI COMPUTER	Convex,Alliant,Vax,etc	Convex,Alliant,Vax
	WORKSTATION	Sun,Apollo,Tek,SiliconG,etc.	Sun,Apollo,TEK
MISCELLANEOUS	CODE EXPERIENCE	No. of years Used	5 yrs
	ORIGIN	In-house,Acquired(Original Code name)	Inhouse,Acq(KIVA,etc.)
	VECTORIZATION	Programed for Vectorization(Yes/No)	Yes/No

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