

Chronology of CAVE Floor Construction
in the ACITC (Torgersen Hall)

By
Ronald D. Kriz
(11-07-00)

Spring of 1997 met with Mr. Bob Livingstone, Capital Project Manager for ACITC building who recommended that I contact Mr. Richard Williams who has worked on a variety of construction projects at Virginia Tech. I contact Mr. Williams who visited us and decided he would be open to working on this project.

On October 18, 1999 I met with key faculty and university officials on the status of construction of the CAVE in the ACITC. Present at the meeting were Professor Ali Nayfeh, Dr. Rick Habayeb, Dr. John Wilson, Dr. Tim Pickering, and myself. Dr. Ken Reifsnider who called the meeting was absent. We first met in a VIMS Conference Room in Hancock Hall where I gave a presentation on the current status which I posted on the Web at <http://www.sv.vt.edu/future/vt-cave/VT/acitic.html>. I explained that as the status of this project changed I would post updates at the top of this Web page. Most critical was the need to proceed to build the CAVE floor support structure for the motion platform in the floor of the CAVE. To emphasize the importance of this construction I brought a 1/8-scale model that I originally made to show Richard Williams. We then proceeded to walk over to the ACITC building that was under construction at the time. I showed the group the 12'x12' hole in the floor and explained that although I had made arrangements to building the CAVE floor support structure, I had no authority or money to pay Mr. Williams and asked for guidance from the assembled group of university officials and key faculty. Professor Nayfeh and Dr. Wilson said to contact Dick Williams and proceed to build the support structure. I contacted Mr. Williams and Mr. Bob Livingstone and we started on the design. There were several meetings with Mr. Livingstone as the design progressed who recommended that I contact Dr. David Ford who was responsible for approving any construction in the ACITC building. I compiled a report summarizing the design and construction (see attached copy of report), that was approved by Dr. Ford under the recommendation of Mr. Livingstone.

Current status of construction is summarized at

http://www.sv.vt.edu/present/ACITC_update_15jun00/



July 6, 2000

Dr. David Ford, Vice Provost for Academic Affairs
330 Burruss Hall
Virginia Tech

Dear Dr. Ford:

Attached is a signed report with complete appendices that describe the details of the construction of a the ACITC CAVE floor that will support the motion base platform. This report states that the proposed structure is safe to operate and will not create annoying sounds to building occupants if operated within the limitations stated in appendix B. We anticipate some minor changes to the design details in appendix A that address fire code and safety issues, but this will not change our conclusions for safe operation.

I have also consulted with Mr. Robert Livingstone who is the Capital Project Manager for the ACITC building and who suggested that I work with Mr. Richard Williams, who is a licensed P.E., on the design and construction of the CAVE floor. Discussions that I have had with Mr. Livingstone clarified that Mr. William's final signed design drawings would satisfy the necessary requirements for safe operation of the ACITC CAVE floor and motion platform. Mr. Livingstone can be contacted at 231-4966 (fpcerdl@vt.edu) if you have any questions with regard to university issues.

Regards,

Ronald D. Kriz, Director
University Visualization and Animation Group of the
Advanced Communications and Information Technology Center

Attachments

Cc: Mr. R. L. Williams
Prof. Tom Murray
Mr. R. D. Livingstone


**Report on the Advanced Communications and Information Technology
Center (ACITC) CAVE Floor Design and Construction**

June 16, 2000


Dr. Ronald D. Kriz, Director
University Visualization and Animation Group of the ACITC
2000 Kraft Dr., Suite 2400, MS 04
Blacksburg, Virginia 20460
(540) 231-2062
rkriz@vt.edu

Signature: _____

Mr. Dick Williams, P.E.
Consulting Engineer Inc.
P.O. Box 20053
3786 Kenwick Trail
Roanoke, Virginia 24018
Phone: (540) 774-5141
Fax (540) 774-5467

Signature: _____

Dr. Thomas M. Murray, Professor
Montague-Betts Professor of Structure Steel
Department of Civil and Environment Engineering (0105)
105A Patton Hall
Virginia Tech
Blacksburg, Virginia 24061
(540) 231-6074
thmurray@vt.edu

Signature: _____

Project Background Chronology:

1. On July 13, 1995 a memorandum was sent to nine "Program Authors" for planning the design of the Advanced Communication and Information Technology Center (ACITC) building. Dr. Ron Kriz was asked to coordinate activities related to "Visualization". "Program Authors" were encouraged to work closely with the ACITC architect to build unique features into the ACITC building that related to their assigned area of expertise.
2. On January 20, 1996, Dr. Kriz along with 27 Co-PIs, submitted a white paper to NSF to build a CAVE Virtual Environment in collaboration with NCSA as an ACITC visualization activity. The white paper was accepted.
3. On February 20, 1996, the NSF-ARI proposal was submitted to NSF to build a CAVE in the ACITC, which was accepted on July 19, 1996.
4. In the Fall of 1996, Dr. Kriz met with the ACITC architect and proposed to build a room that would contain a glass floor and sufficient ceiling height that would allow ceiling projection for a future upgrade to the existing CAVE.
5. In the Spring of 1997, Dr. Kriz met with Mr. Robert Livingstone, university ACITC Capital Project Manager, who recommended Mr. Richard Williams design the ACITC CAVE floor support structure.
6. On July 5, 2000, Dr. Kriz, Dick Williams, Scott Easter (A&E), and Chuck Smith (A&E) met with Mr. Robert Livingstone to discuss final revisions in the design. Modifications include: 1) replace all wooden components with steel and/or fiber-reinforced concrete panels and 2) construct a safety skirt around the motion platform prior to occupancy with barrier to the CAVE entrance during operation, and 3) construct a safety net which will be used during the installation and removal of the motion platform chair.
7. The CAVE floor support structure is scheduled for construction mid-July 2000.

Project Summary of Design and Construction:

Details of the design and construction of the ACITC CAVE floor support structure are located in the Appendices. Appendix A describes the support structure design criteria and construction, and Appendix B describes vibration analysis of motion platform.

In summary, the support structure has been designed for both static, dynamic, and fatigue based on: 1) Virginia Uniform Statewide Building Code, 2) BOCA National Building Code, 3) ASCE-9, and 4) ANSI / AF & PA NDS. Discussion with Mr. Livingstone clarified that these design codes meets the requirements for safe operation of the CAVE floor support structure and existing ACITC building structure.

Preliminary results of dynamics analysis, located in Appendix B, strongly show that the motion platform will operate within safe limits of the existing ACITC building and support structure designed in Appendix A. Detailed analysis is pending. At worst the operation of the motion platform will result in a noise problem that can be controlled by providing operational limits to the operation of the motion platform. If the motion platform operation exceeds noise limits perceived by ACITC occupants then operation will be scheduled when the ACITC occupants are not in the building. Detailed dynamic analysis will provide information for operational limits. We recommend another dynamic analysis of the motion platform when installed will result in more accurate operational guidelines.

We recommend that an operational log of motion platform usage and annual visual inspection of support structure bolts although not necessary will provide an additional margin of safety.

Appendix A

Design Criteria and Construction of ACITC CAVE floor
substructure and existing ACITC building structure.

RICHARD L. WILLIAMS

CONSULTING ENGINEER, INC.

3786 KENWICK TRAIL

P.O. BOX 20053

ROANOKE, VIRGINIA 24018

PHONE (540) 774-5141

FAX (540) 774-5467

June 9, 2000

Virginia Polytechnic Institute
And State University
Materials Response Group
Blacksburg, Virginia 24061

Att: Ronald Kriz

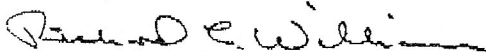
Comm. Renovation and Relocation VT Cave
021599

Dear Sir,

I am submitting to you a copy of design criteria, general information and information on materials (steel and wood) to be used on the project. This information will be shown on the contract documents to establish the design, fabrication and construction requirements for the project.

If there are any specific items you have questions on please let me know.

Sincerely,



Richard L. Williams PE

RICHARD L. WILLIAMS**CONSULTING ENGINEER, INC.**

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DESIGN CRITERIA

(cave vt 021599) Pg. 1

1. Governing Codes: (latest edition)

Virginia Uniform Statewide Building Code
BOCA National Building Code
ASCE --9
ANSI / AF & PA NDS

2. Live Loads

Floor 100 psf

3. Dead Loads

Motion Mechanics 3600 pounds

GENERAL NOTES

1. The contractor shall field verify all dimensions of existing construction that affects new construction prior to submission of shop drawings or fabrication. Any variances from the plans shall be reported.

2. The contractor shall provide adequate bracing for the structure so that it will be stable during all stages of construction.

STEEL

1. All structural steel, unless otherwise noted, shall conform to the requirements of ASTM A-36.

2. All detailing, fabrication and erection of structural steel, unless otherwise noted, shall conform to the requirements of the AISC specifications for buildings, and design, 9th edition.

3. Unless otherwise noted, all shop connections shall be made by welding or high strength bolting ($\frac{3}{4}$ inch dia. bolts).

4. Unless otherwise noted, welds shall be made with E-70 electrodes.

5. Unless otherwise noted, all field connections shall be made with $\frac{3}{4}$ inch dia. high strength bolts (ASTM A-325). Connections shall be designed as bearing type with threads in the shear plan.

6. Unless otherwise shown, all beam connections shall be standard framed as shown in part 4 of the AISC Manual of Steel Construction. Unless reactions are indicated on the plan, connections shall develop at least one-half of the total uniform load capacity tabulated in the tables of the manual for the given shape

and span of the beam. However in no case shall the length of connection be less than one-half of the "T" dimension of the beam web. Also, a 2-bolt connection will be the minimum allowable.

WOOD

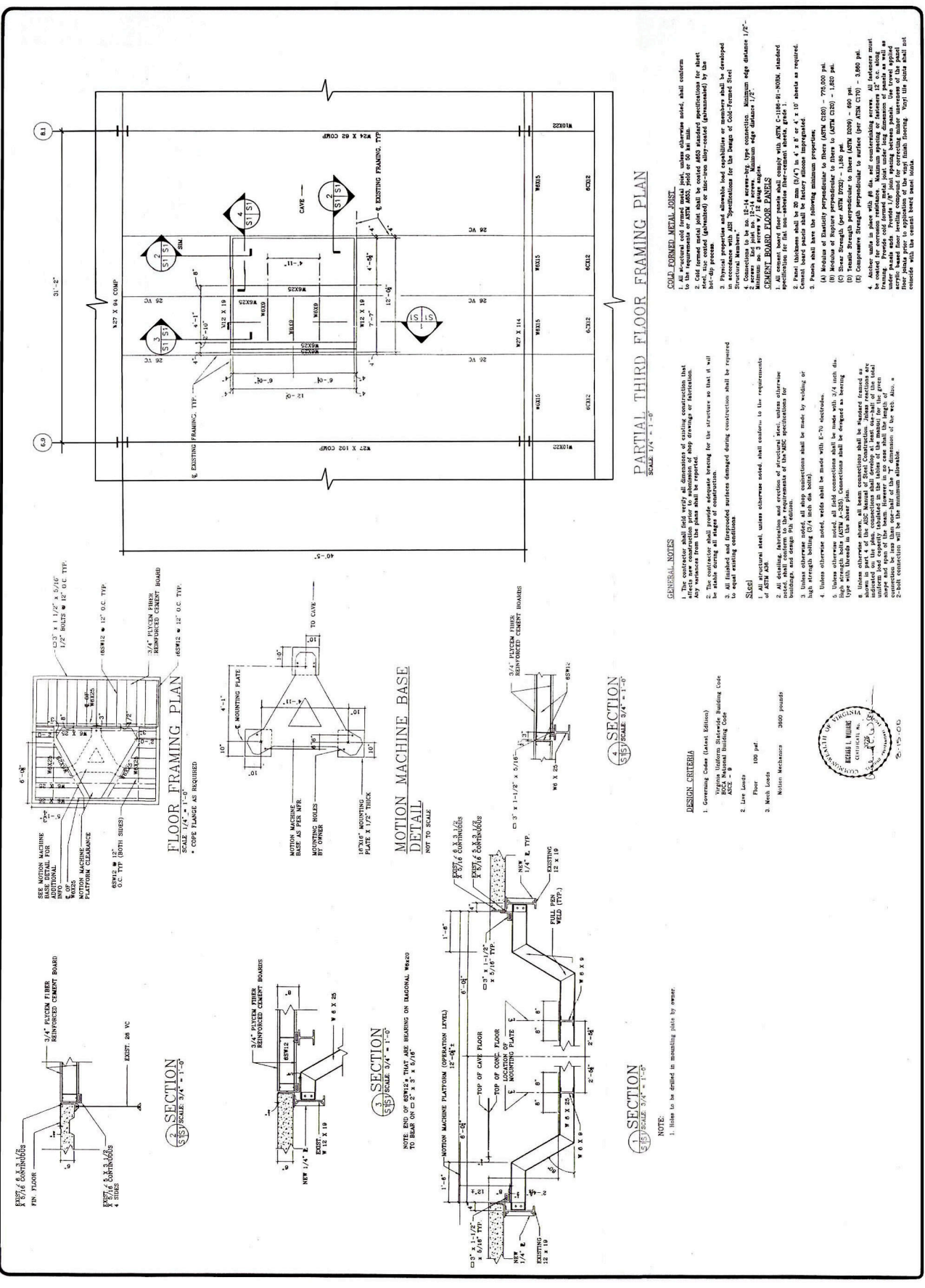
1. All wood beams and joist shall be select structural southern pine.
2. Flooring to be $\frac{3}{4}$ inch tongue and groove plywood.
3. Bolts for wood connections to be $\frac{1}{2}$ inch ANSI- ASME B18-2.1 unless otherwise noted.

NO.	REVISIONS

RICHARD L. WILLIAMS
CONSULTING ENGINEER, INC.
3796 KENWICK TRAIL
P.O. Box 20028
Roanoke, Virginia 24118
(540) 774-1111

PARTIAL FRAMING PLAN - MOTION MACHINE
BLACKSBURG, VIRGINIA

DATE	8-10-00
BY	RLW
CHECKED	
SCALE	AS NOTED
NO.	8-10-00
SHEET	15



GENERAL NOTES:

- Items to be checked in mounting plate by owner.



Material Response Group
Department of Engineering Science and Mechanics
Mail Code 0219, 120 Patton Hall
Blacksburg, Virginia 24061

September 18, 2000

Att: Ronald Kriz

Ref. Renovation and Relocation VT Cave
021599

Structural Services Provided:	Contract Documents	
Engineering 175 Hours @ \$ 50.00		\$ 8,750.00
Documents CAD		2,280.00
Expenses (mileage)		<u>252.0</u>
		\$11,282.00

RICHARD L. WILLIAMS

CONSULTING ENGINEER, INC.

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FAX (540) 774-5467

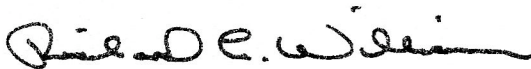
Mr. Ronald Kriz
Material Response Group
Department of Engineering Science and Mechanics
Virginia, Tech
Mail Code 0219, 120 Patton Hall
Blacksburg, VA 24061

September 18, 2000

Dear Mr. Kriz,

I am sending to you a statement of my cost to date for the structural services provided. If you have any questions on the statement are services required during the construction phase please feel free to call.

Regards,



Richard L. Williams P.E.

RICHARD L. WILLIAMS

CONSULTING ENGINEER, INC.

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ROANOKE, VIRGINIA 24018

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Field Report

February 22, 2001

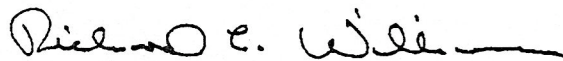
Ref: VT Cave

Date: January 10, 2001

Contact: Johnny Jerels
Comfort Systems

Task: Completing the installation of the fiber cement board.

Comments: Observed the installed light gage metal joist and a portion of the fiber cement board.
The materials are as required on the contract document and the workmanship is
Excellent. If there are any questions let me know.



Richard L. Williams PE

RICHARD L. WILLIAMS

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PHONE (540) 774-5141

FAX (540) 774-5467

Mr. Paul Siburt
ESM Virginia Tech
Mail Code 0219
Blacksburg, VA 24061

February 23, 2001

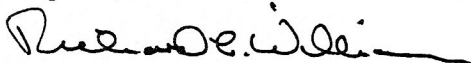
Ref: Relocation and Renovations VT Cave
021599 VTC

Dear Mr. Siburt,

I am submitting to you my final field report stating the motion machine support and cave floor and floor support has now been completed. My construction services are also complete and you will find a statement of services enclosed.

Thank you for the opportunity to be a part of the cave community and if there are any questions let me know.

Regards,



Richard L. Williams PE

Copy: Ron Kriz, Paul Ely

RICHARD L. WILLIAMS

CONSULTING ENGINEER, INC.

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PHONE (540) 774-5141

FAX (540) 774-5467

Mr. Paul Siburt
ESM
Virginia Tech
Mail Code 0219
Blacksburg, VA 24061

February 23, 2001

Ref: Renovations and Relocation VT Cave
021599

Structural Services Provided: Coordination with contractor, Shop Drawing Review, and Three Project Reviews.

Lump Sum

\$ 1250.00

Appendix B

Vibration Analysis of ACITC CAVE floor structure

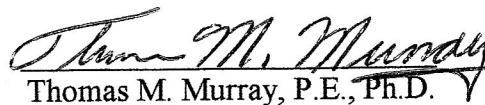
Summary of Vibration Readings for CAVE

Submitted to
Ronald D. Kriz
Virginia Polytechnic Institute and State University

Readings for the AITC building and CAVE room were taken on two separate days. The first readings taken on May 18, 2000 included various heel drop and ambient readings in the existing CAVE room. Readings in the AITC building included ambient, heel drop, and walking measurements in the Visualization and Animation Lab. Heel drop tests were performed at the site of the new CAVE located in the AITC building. Readings on May 22, 2000 were all acquired in the existing CAVE location. Another heel drop test was executed. All other readings taken were of the floor response generated by the motion platform undergoing different motions.

The floor of the existing CAVE exhibited a fundamental natural frequency of 6.25 to 6.75 Hz. The proposed site for the new CAVE showed a much stiffer system with a response ranging from 10.00 to 15.00 Hz. The Visualization and Animation lab demonstrated a fundamental natural frequency of 7.50 to 8.25 Hz. A summary of results for each test can be found in the table on the following page.

It is my opinion that the motion platform can be operated in the AITC building safely and without causing vibrations that will be annoying or disruptive to other building occupants.


Thomas M. Murray, P.E., Ph.D.

Department of Civil and Environmental Engineering

Location	Record No.	Excitation	f1 (Hz)	a peak - f1 (%g)	f2 (Hz)	a peak - f2 (%g)	f3 (Hz)	a peak - f3 (%g)	a rms (%g)	a peak (%g)	
2000 Kraft Building											
Outside CAVE	126-128	Heel Drop	6.75	0.15000	6.25	0.14140	32.75	0.09051	0.9274	10.6700	
Outside CAVE	129-131	Ambient	31.75	--	50.75	--	6.25	--	--	--	
Beside Motion Platform	147-149	Heel Drop	6.75	0.29640	11.75	0.08501	14.50	0.05393	1.0250	3.2810	
Beside Motion Platform	150-152	Motion Platform -- smooth periodic rotation with period t = 2 sec	37.00	0.07646	37.50	0.06230	4.00	0.05716	0.3235	0.9860	
Beside Motion Platform	153-155	Motion Platform -- periodic horizontal translation with period t = 2 sec	45.75	0.08745	47.25	0.07329	40.25	0.07301	0.4703	1.5940	
Beside Motion Platform	156-158	Motion Platform -- vertical sinusoidal periodic motion with period t = 1.0 sec	7.00	0.95450	5.00	0.34620	45.00	0.28630	1.5080	5.5030	
Beside Motion Platform	159-161	Motion Platform -- vertical sinusoidal periodic motion with period t = 0.5 sec	6.00	1.58800	22.00	0.34190	18.00	0.33760	1.9560	5.1610	
Beside Motion Platform	162-164	Motion Platform -- vertical sinusoidal periodic motion with frequency f = 6.75 Hz	6.75	7.32200	20.25	1.43700	33.75	1.37500	8.1860	12.0700	
On Motion Platform	165-167	Motion Platform -- small vertical sinusoidal periodic motion with period t = 0.5 sec	2.00	29.65000	58.25	2.69300	62.25	2.29100	30.7500	41.0900	
AITC Building											
Open Side 18 inches from edge of hole	132-134	Heel Drop	15.50	0.08030	36.00	0.07571	14.00	0.07406	0.7964	8.0720	
Right Side about 3 feet from hole edge	135-137	Heel Drop	10.00	0.17830	10.50	0.15540	13.75	0.10810	0.8992	5.6930	
Visualization and Animation Lab	138-140	Heel Drop	8.25	0.20750	10.25	0.10180	45.75	0.09297	1.0310	10.9300	
Visualization and Animation Lab	141-143	Walking Perpendicular	7.50	0.11660	8.50	0.10370	9.25	0.05753	0.2826	1.2670	
Visualization and Animation Lab	144-146	Walking Parallel	7.75	0.11920	9.75	0.08487	8.50	0.06356	0.3142	1.5530	

Reading Dates: 5/18/00 Records 126-146
5/22/00 Records 147-167

Date: Wed, 12 Jul 2000 11:33:55 -0400
From: fpcrdl@exchange.vt.edu
To: fordd@vt.edu
Cc: rkriz@vt.edu, drb@vt.edu, lynnk@vt.edu, stockr@vt.edu
Subject: RE: Kriz report

[The following text is in the "iso-8859-1" character set.]
[Your display is set for the "US-ASCII" character set.]
[Some characters may be displayed incorrectly.]

David:

I have reviewed the June 16, 2000 Report outlining the proposed design/construction of structure to support a "motion machine" and floor system in the ACITC Virtual Reality Cave.

It appears that conceivable concerns have been addressed;

- * Structural analysis and design in accordance with referenced Codes has been accomplished by a licensed Structural Engineer.
- * Dynamics analysis has been performed by a licensed Civil Engineer having related discipline expertise.
- * Capital Design and Construction design recommendations, concerning "safety" and the use of "appropriate noncombustible materials" consistent with the Building Construction Type, will be incorporated into the final system design.
- * Proposed "operational guidelines" should ensure that safety is maintained, and confirm or adjust expected motion machine use in response to noise perceptions of building occupants.

Regards,
RDL.

> -----Original Message-----

> From: David Ford [mailto:fordd@vt.edu]
> Sent: Tuesday, July 11, 2000 10:06 PM
> To: fpcrdl@vt.edu
> Cc: stockr@vt.edu
> Subject: Kriz report

>

>

> Robert-----

>

> Have you read the Kriz report on the CAVE motion platform? If so do
> you concur that we can give Ron permission to proceed? If you
> concur, I have drafted a letter to go to Ron stating that he can
> proceed and listing the conditions (taken from the report) under
> which the motion platform can be used. I will copy my MOU to you,
> Ken Reifsnider, Scott Macrae and Rich Stock for the record.

>

>


> -----Thanks, David

>



Memorandum of Understanding

MEMORANDUM

TO: Dr. Ronald D. Kriz
FROM: David R. Ford 
DATE: July 13, 2000
RE: ACITC CAVE Floor and Motion Base Platform

Thank you for the report describing the details of the construction of the ACITC CAVE floor that will support a motion base platform. Upon receiving the report I discussed these recommendations in the report with Mr. Robert Livingstone, Capital Project Manager for the ACITC building. Mr. Livingstone and I agree that the construction of the CAVE floor and the motion platform should proceed according to specifications with the following understanding:

1. that an "in situ" dynamic analysis be conducted after placement in the ACITC CAVE space,
2. that, based on the "in situ" dynamic analysis, a formal, written operational limits document be prepared and filed with the Facilities Design and Construction Office and the ACITC building manager,
3. authorization for ongoing operations of the motion platform will be conditioned on the CAVE operators adhering to the prescribed operational limits, the objective and subjective tolerance(s) of other ACITC occupants, and ongoing anecdotal evidence that operation of the platform does not cause any building damage, and,
4. an operational log of motion platform usage must be maintained including an annual visual inspection of support structure bolts.

Please contact me if you have questions about this memorandum of understanding.

DRF/lsp

Cc: R. D. Livingstone
K. L. Reifsnider
S. R. Macrae
R. H. Stock