

NCST Investigation of the Champlain Towers South Collapse

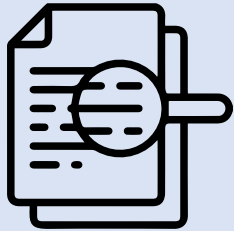
Concluding Remarks and Next Steps

Glenn Bell

Associate Lead Investigator

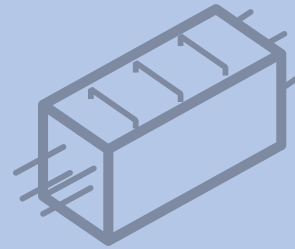
glenn.bell@nist.gov

Theme 1:
***Timeline and Evidence
Collection***



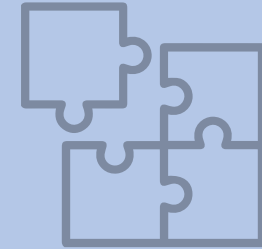
*Judith Mitrani-Reiser,
N. Emel Ganapati, David Goodwin,
Christopher Segura,
Jonathan Weigand, Kam Saidi,
Jack Moehle*

Theme 2:
***Analysis and Testing
Updates***



*Fahim Sadek, James Harris,
Christopher Segura,
Kenneth Hover, Jack Moehle,
Sissy Nikolaou*

Theme 3:
***Analysis of Failure
Hypotheses***



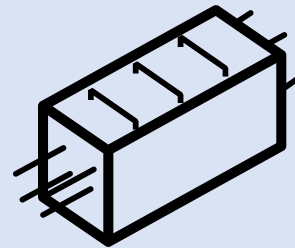
*Glenn Bell, Fahim Sadek,
Georgette Hlepas,
Scott Jones, James Harris,
Youssef Hashash*

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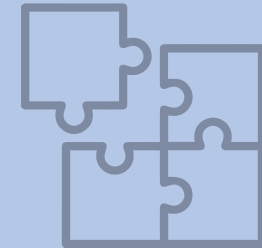
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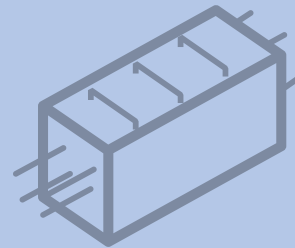
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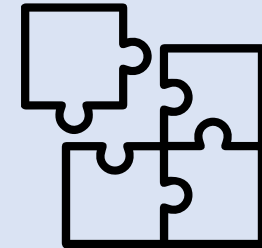
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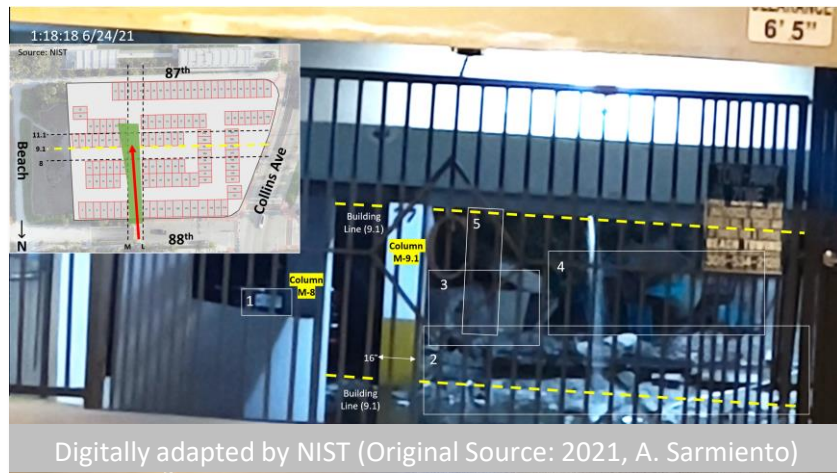
*Glenn Bell, Fahim Sadek,
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Failure Sequence and Preliminary Data and Analyses

NIST has made no findings or recommendations based on the preliminary data and analyses presented, which are subject to change.

Failure Sequence

1. The pool deck collapsed between its southern extremity and its connection to the tower more than four minutes before the general collapse of the tower.



NIST's Analysis of CTS Parking Garage Ramp Video Footage



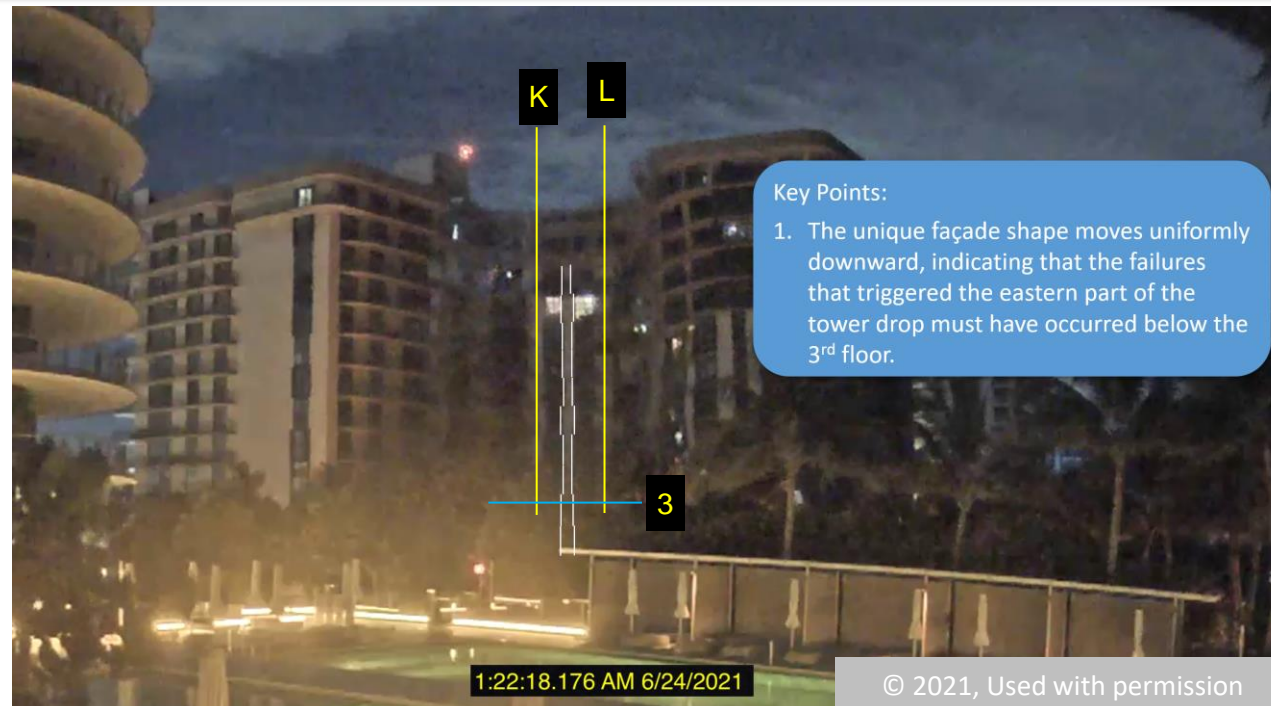
NIST's Analysis of Beach Access Walkway Video Footage



Eyewitness Accounts of Pool Deck Collapse

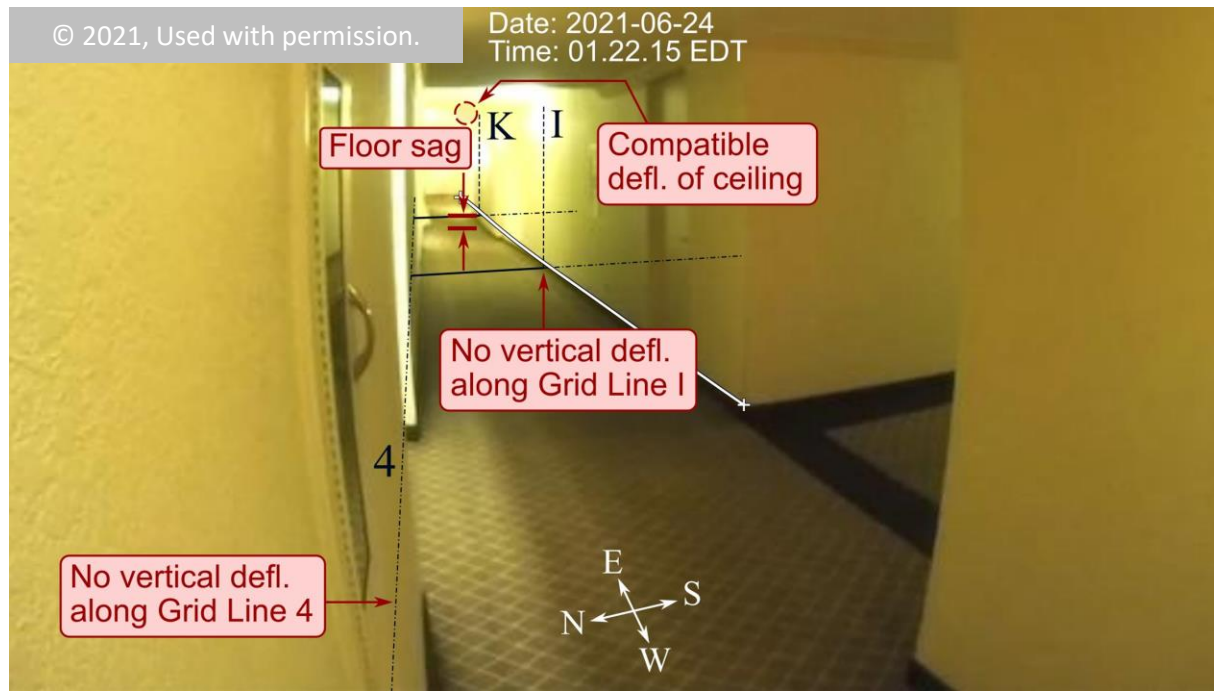
Failure Sequence

2. In the tower collapse, Grid Line 9.1 started to drop a second, or a bit more, before 1:22:17 am, the time of the first frame of the South Face Video.
- The columns on Grid Line K and/or L dropped first.
 - The initial column failures were low in the building, at or below the 3rd floor.



Failure Sequence

3. Videos show severe structural movements in the tower between Grid Lines K and M and Grid Lines 4 and 9.1 prior to the precipitous drop of the tower along Grid Line 9.1.



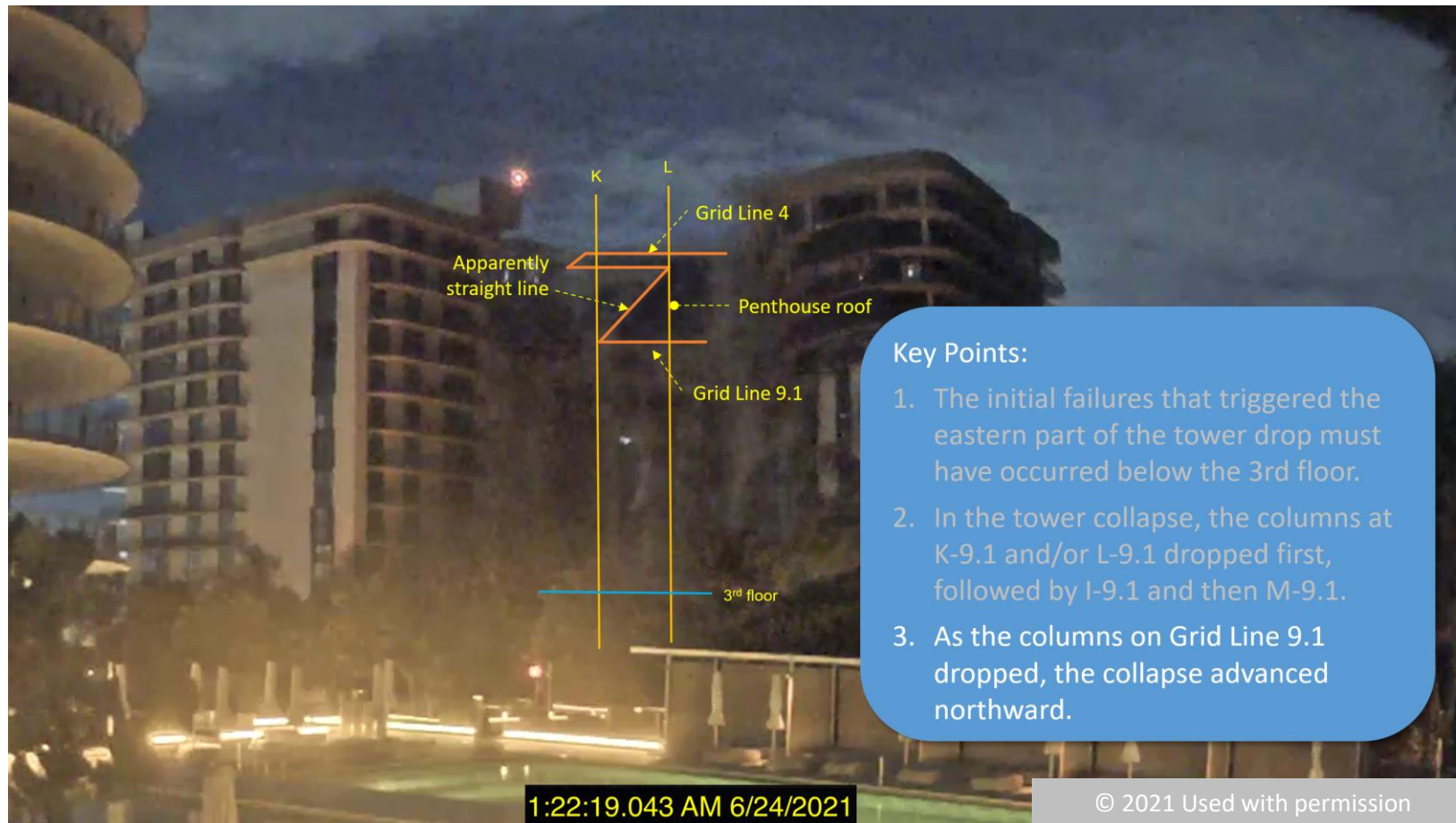
NIST's Analysis of Upper Story Corridor Video Footage



NIST's Analysis of 11 Stack Unit Video Footage

PRELIMINARY ANALYSIS RESULTS

4. As the columns on Grid Line 9.1 dropped, the collapse advanced northward.



Key Points:

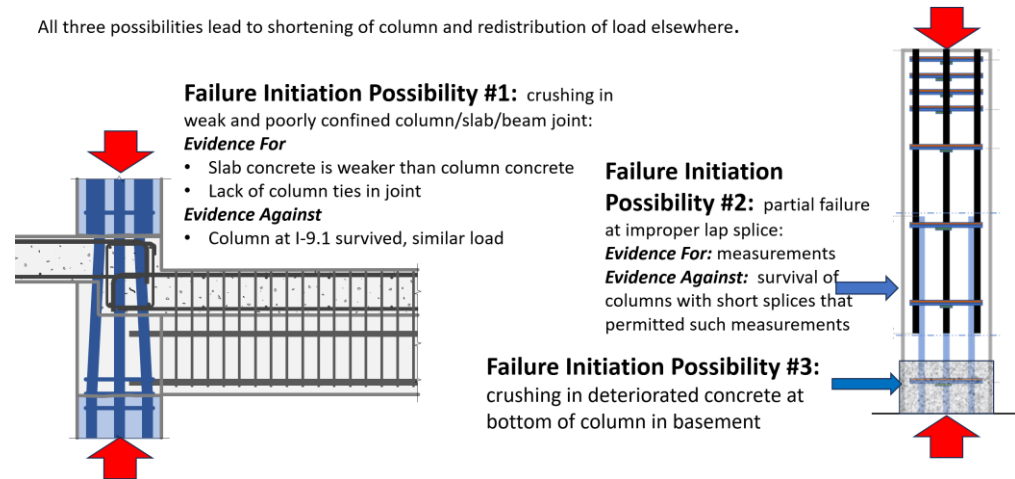
1. The initial failures that triggered the eastern part of the tower drop must have occurred below the 3rd floor.
2. In the tower collapse, the columns at K-9.1 and/or L-9.1 dropped first, followed by I-9.1 and then M-9.1.
3. As the columns on Grid Line 9.1 dropped, the collapse advanced northward.

Failure Sequence

5. While there is strong evidence that the collapse initiated in the pool deck, we have not yet ruled out a failure initiation in some part of the tower that precipitated a collapse in the pool deck.
- There were indications of severe distress in the pool deck at least three weeks before the collapse.
 - There are also potential initiation points in the tower.



Damage to Pool Deck Planters Three Weeks Before the Collapse Indicated Severe Structural Distress



Examples of Failure Initiation Possibilities in the Tower

Failure Sequence

- 1.** The pool deck collapsed between its southern extremity and its connection to the tower more than four minutes before the general collapse of the tower.
- 2.** In the tower collapse, Grid Line 9.1 started to drop a second, or a bit more, before 1:22:17 am, the time of the first frame of the South Face Video.
- 3.** Videos show severe structural movements in the tower between Grid Lines K and M and Grid Lines 4 and 9.1 prior to the precipitous drop of the tower along Grid Line 9.1.
- 4.** As the columns on Grid Line 9.1 dropped, the collapse advanced northward.
- 5.** While there is strong evidence that the collapse initiated in the pool deck, we have not yet ruled out a failure initiation in some part of the tower that precipitated a collapse in the pool deck.

Preliminary Data and Analyses

1. The structural design of pool deck and tower of Champlain Towers South failed to meet the strength and prescriptive requirements of the applicable building code.

- The instances of design understrength were far more severe in the pool deck than in the tower.
- Deviations from prescriptive code requirements for reinforcement detailing, concrete cover, and relative strengths of column vs. floor concrete.

Original codes: SFBC* 79 / ACI^ 318-77
Current codes: ASCE† 7-22 / ACI 318-19

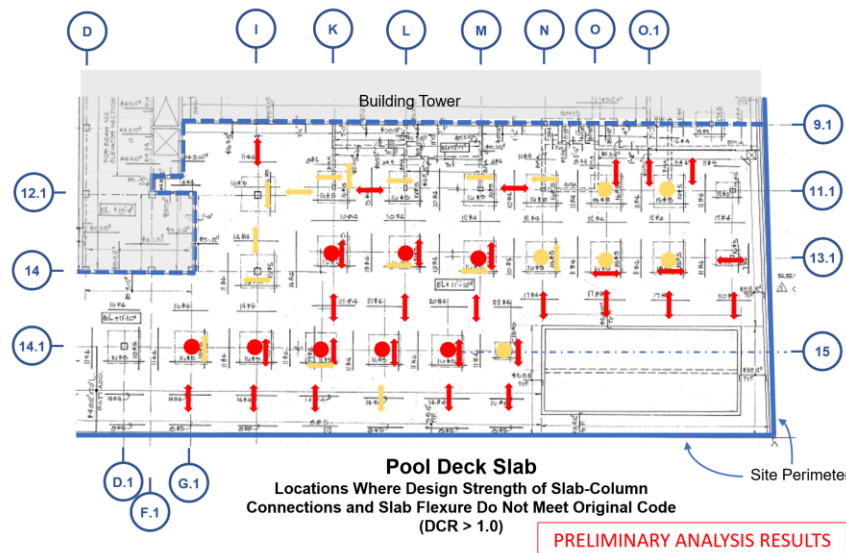
*South Florida Building Code
^American Concrete Institute
†American Society of Civil Engineers

Key Preliminary Observations:

- Pool Deck: design strength does not comply with the original codes and standards, with many areas of severe strength deficiency.
- Tower: work in progress.

Figure Legend

Degree of Understrength	Location of Understrength	
	slab-column connections	slab flexure
severe	●	→
moderate	●	→

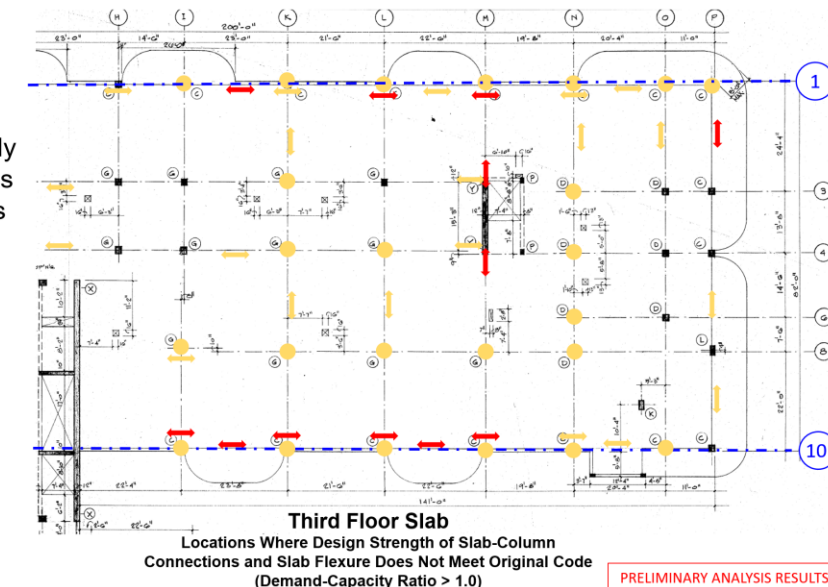


Third Floor Key Preliminary Observations:

- Design strength does not comply with the original or current codes and standards, with many areas of strength deficiency.

Figure Legend

Degree of Understrength	Location of Understrength	
	slab-column connections	slab flexure
severe	●	→
moderate	●	→



Preliminary Analysis of the Design of the CTS Pool Deck

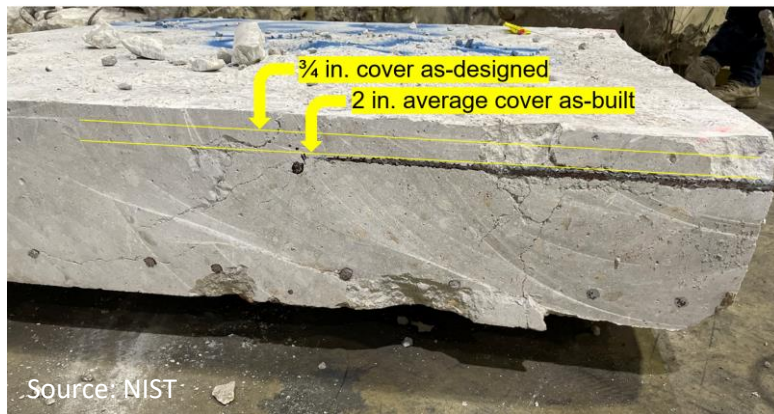
PRELIMINARY ANALYSIS RESULTS

Preliminary Analysis of the Design of the CTS 3rd Floor Slab

Source original design drawing underlay: Town of Surfside

Preliminary Data and Analyses

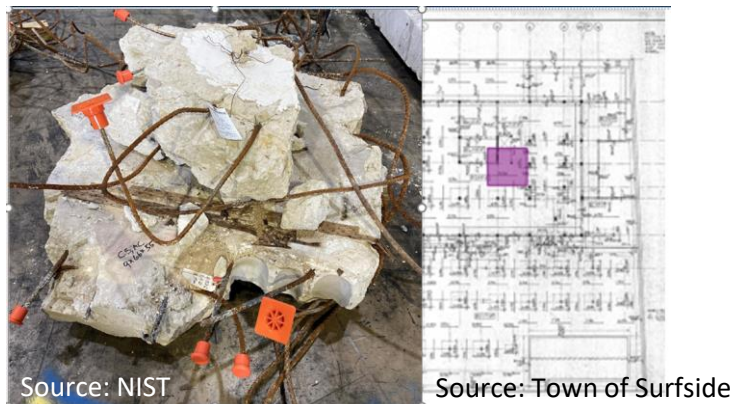
2. The placement of steel reinforcement and alignment of concrete during construction failed to meet the requirements of the structural design documents in multiple respects.



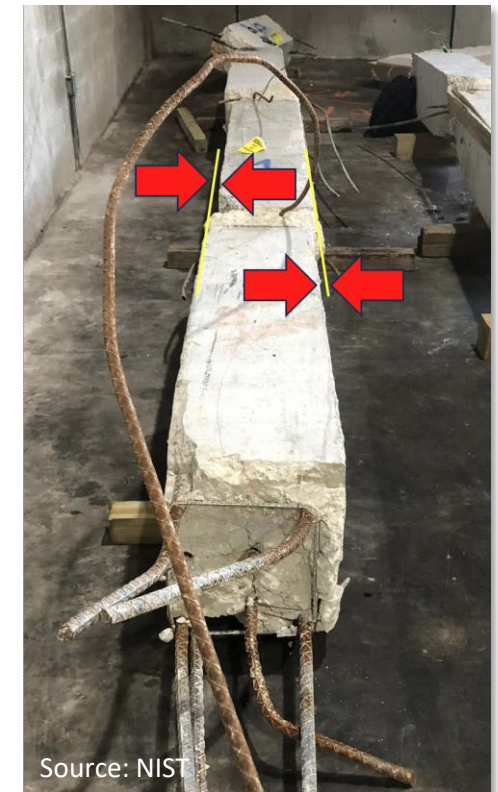
Top Reinforcement Lower Than Design Requirements



Position of Reinforcement Cage Within Columns



Placement of Top Bars in Column Strips

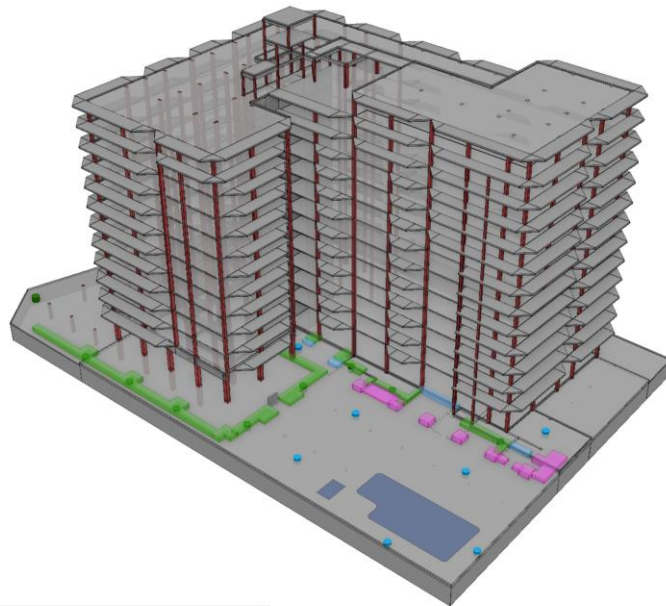


Alignment of Concrete

PRELIMINARY ANALYSIS RESULTS

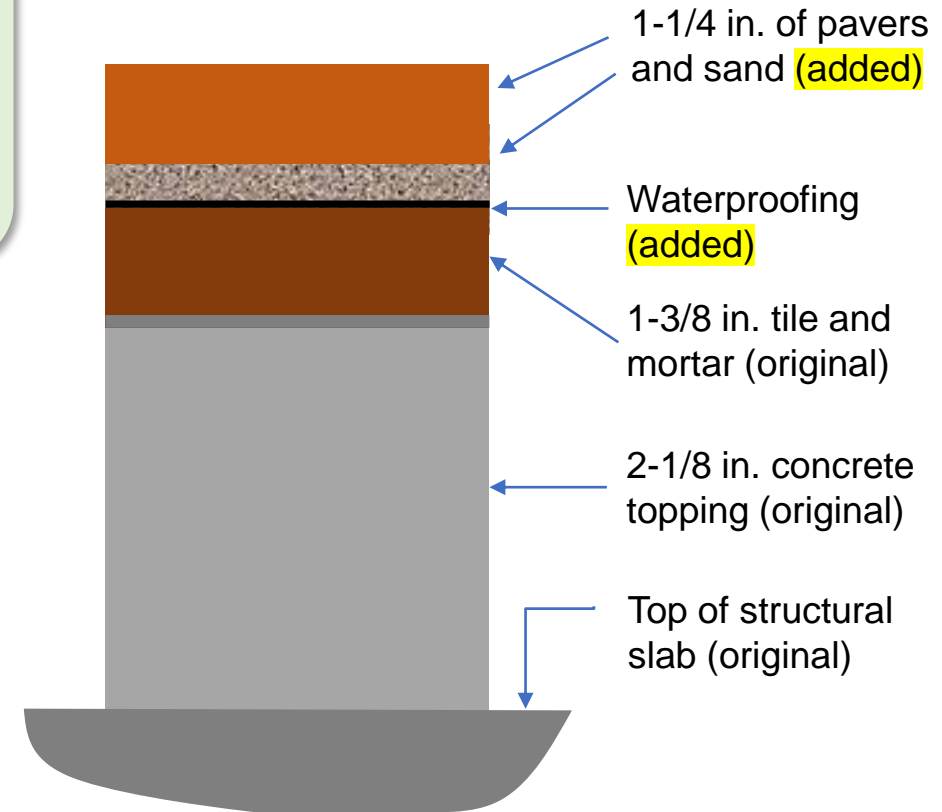
Preliminary Data and Analyses

3. In the pool deck, the extent of landscaping planters was greater than shown on the original design documents, and fill and paving were added over the life of the structure, increasing the loads on the pool deck structure.



Type
Additional (NOT Included in Design)
As-Designed
As-Designed (NOT PRESENT)

Added Planters

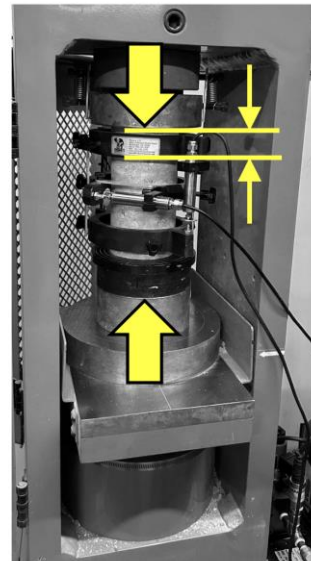


Added Waterproofing,
Sand, and Pavers

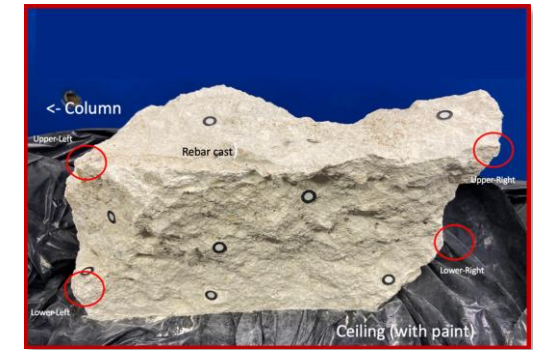
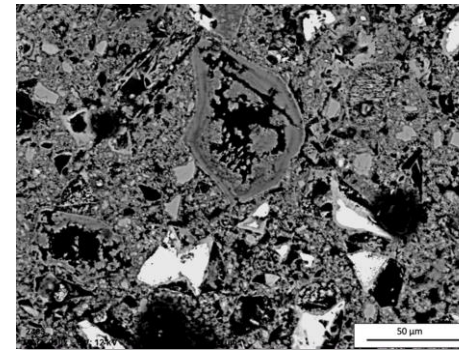
Preliminary Data and Analyses

4. Extensive testing of the mechanical properties of concrete and steel is ongoing. Concrete strength test results to date are widely variable in some parts of the structure requiring additional analysis and testing.

Concrete Compression Strength & Modulus of Elasticity (ASTM C39, C42, C469)



5. Study of degradative mechanisms in the concrete is ongoing.

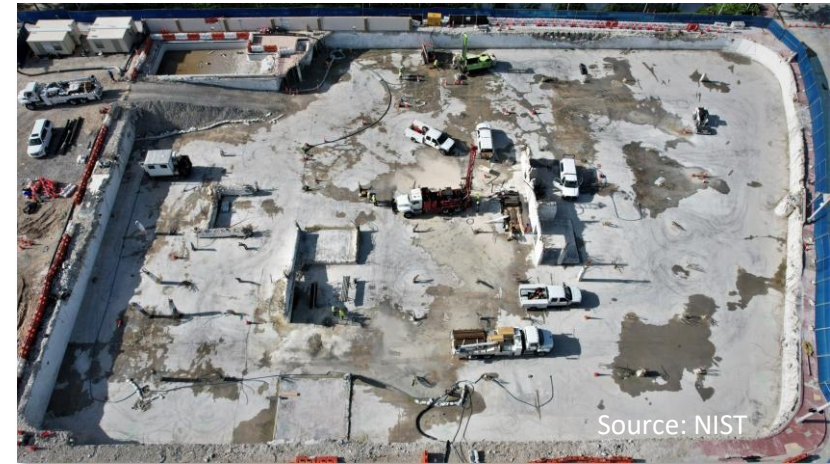


6. Some of the reinforcement in the pool deck exhibits corrosion. We continue to analyze the extent and consequences of this corrosion.



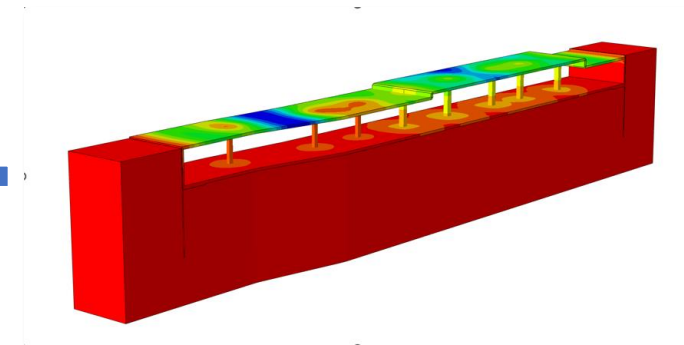
Preliminary Data and Analyses

7. Geotechnical evaluations to date shows no evidence of large karstic voids that impacted the CTS foundations.



Site Investigation Included 70 Boreholes and Cone Penetrometer Tests

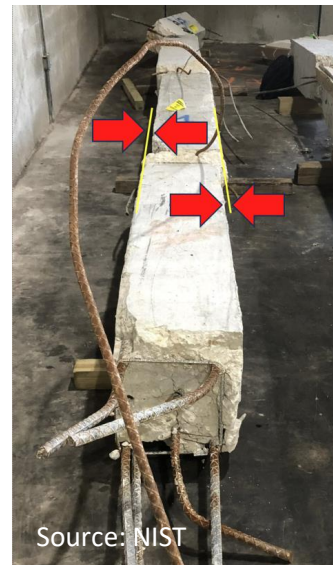
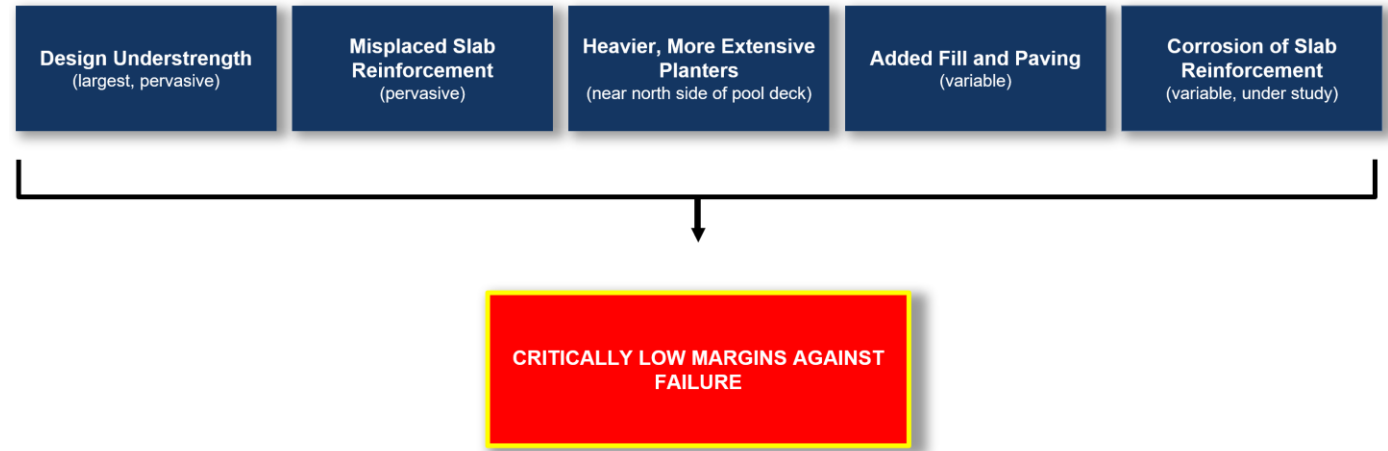
8. Geotechnical and structural evaluations to date show that estimated potential foundation settlements under structural loading were small and had minimal impact on the pool deck structure.



Analysis of Pile Differential Settlements

9. Structural margins against failure in some areas of the pool deck were critically low at the time of the building's collapse.

10. We continue to study the consequences of numerous potential causes and contributors to initiation hypotheses in the tower.



Concrete and reinforcement cage misalignment



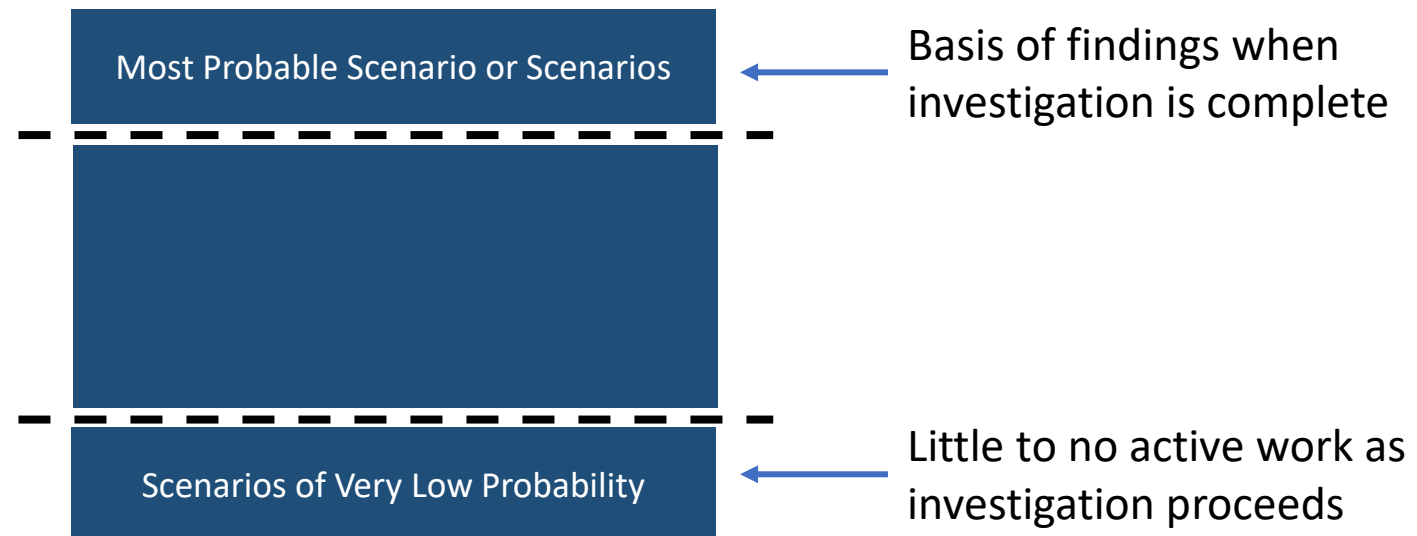
PRELIMINARY ANALYSIS RESULTS

Analyzing and Rating Failure Hypotheses

Analyzing and Rating Failure Hypotheses

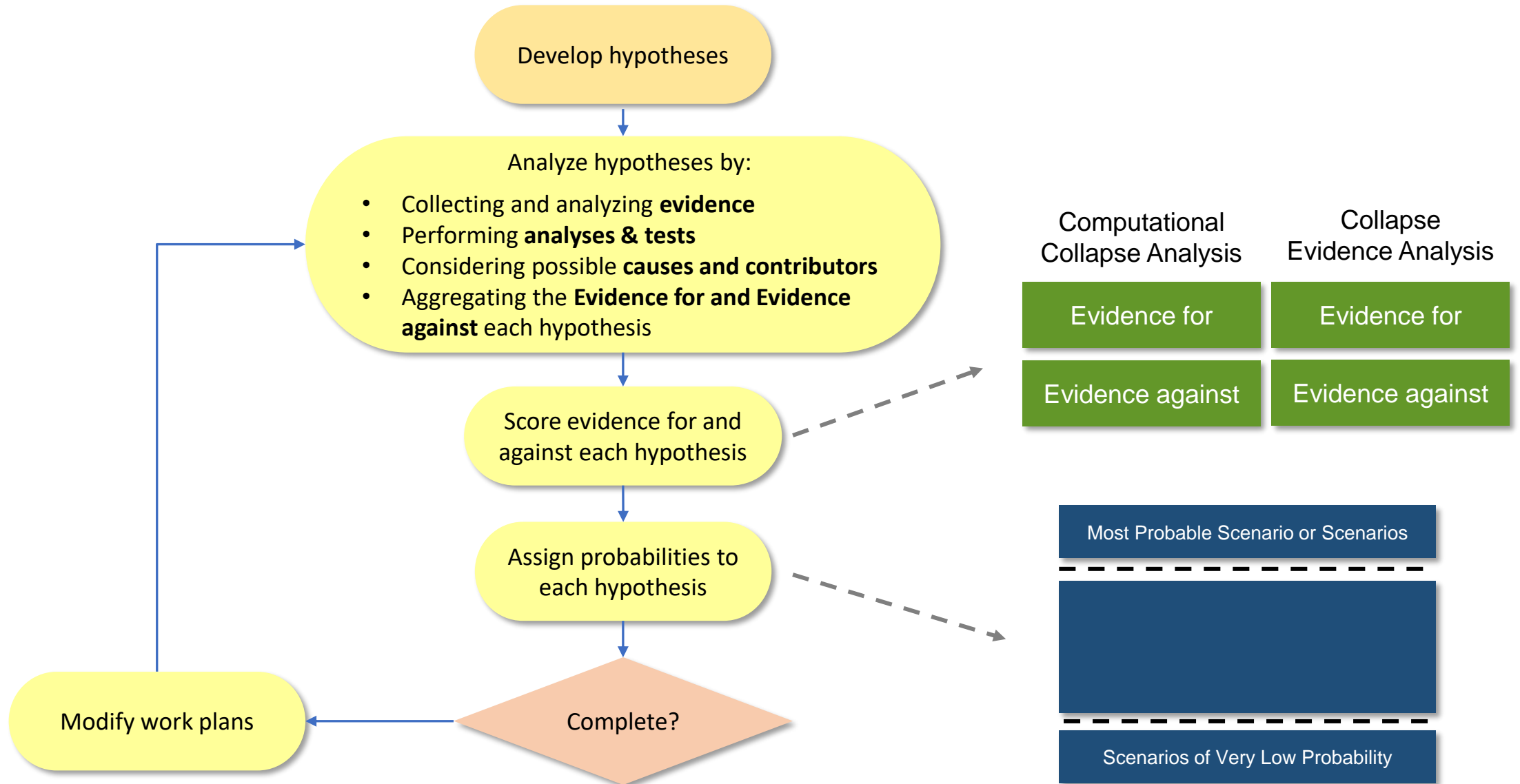
1. Investigation charge: **“Identify the most probable cause or causes of the partial collapse.”**
2. NCST Advisory Committee: **“How do you know when to stop pursuing a particular hypothesis?”**

Assess the probability of each hypothesis



List of Hypotheses Ordered by Probability, High to Low

Analyzing and Rating Failure Hypotheses

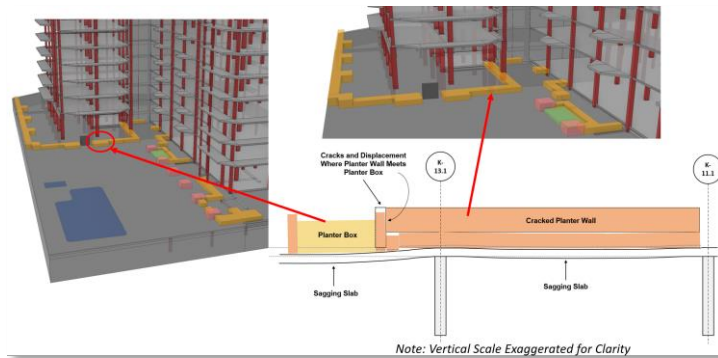


Communication of NIST's Findings and Recommendations

Two Forms of Communication of NIST's Findings and Recommendations*

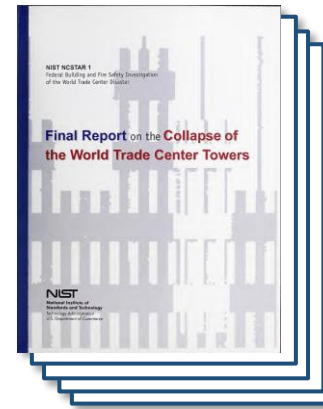
On-Line Experience Tailored to the General Public

- Broad in scope but with communication readily accessible to the public
- Graphical presentations



Interactive on-line experience. 2-D and 3-D graphics, videos, and animations

Multi-Volume Formal Report Similar to NIST's NCSTAR 1 WTC Reports



- A comprehensive, detailed description of the investigation, its findings, and its recommendations
- One overarching summary report with multiple sub-reports in a nested organization
- The language of the summary report will be intentionally accessible to the public
- Pdf format

Summary report: several hundred pages. Dozens of supporting volumes. Thousands of pages in total.

* These forms of communication will be supplemented by a broad program of public outreach and communications developed in collaboration with NIST's Public Affairs Office.

CTS Report Hierarchy

Level 1: Investigation Summary

NCSTAR 5

Overarching Summary Report:

- Principal findings
- Recommendations

Level 2: Topical Reports

NCSTAR 5-n

Approximately 10 to 12

Examples:

NCSTAR 5-n
Social Science

NCSTAR 5-n
Timelines

NCSTAR 5-n
Materials Science

NCSTAR 5-n
Analysis of Failure Hypotheses

Level 3: Supporting Documents

Supporting Document Types

NCSTAR 5-n-a reports

Appendices to NCSTAR 5-n reports

NCSTAR GCRs

Outline of NCSTAR 5
Final Report on the Partial Collapse of Champlain Towers South

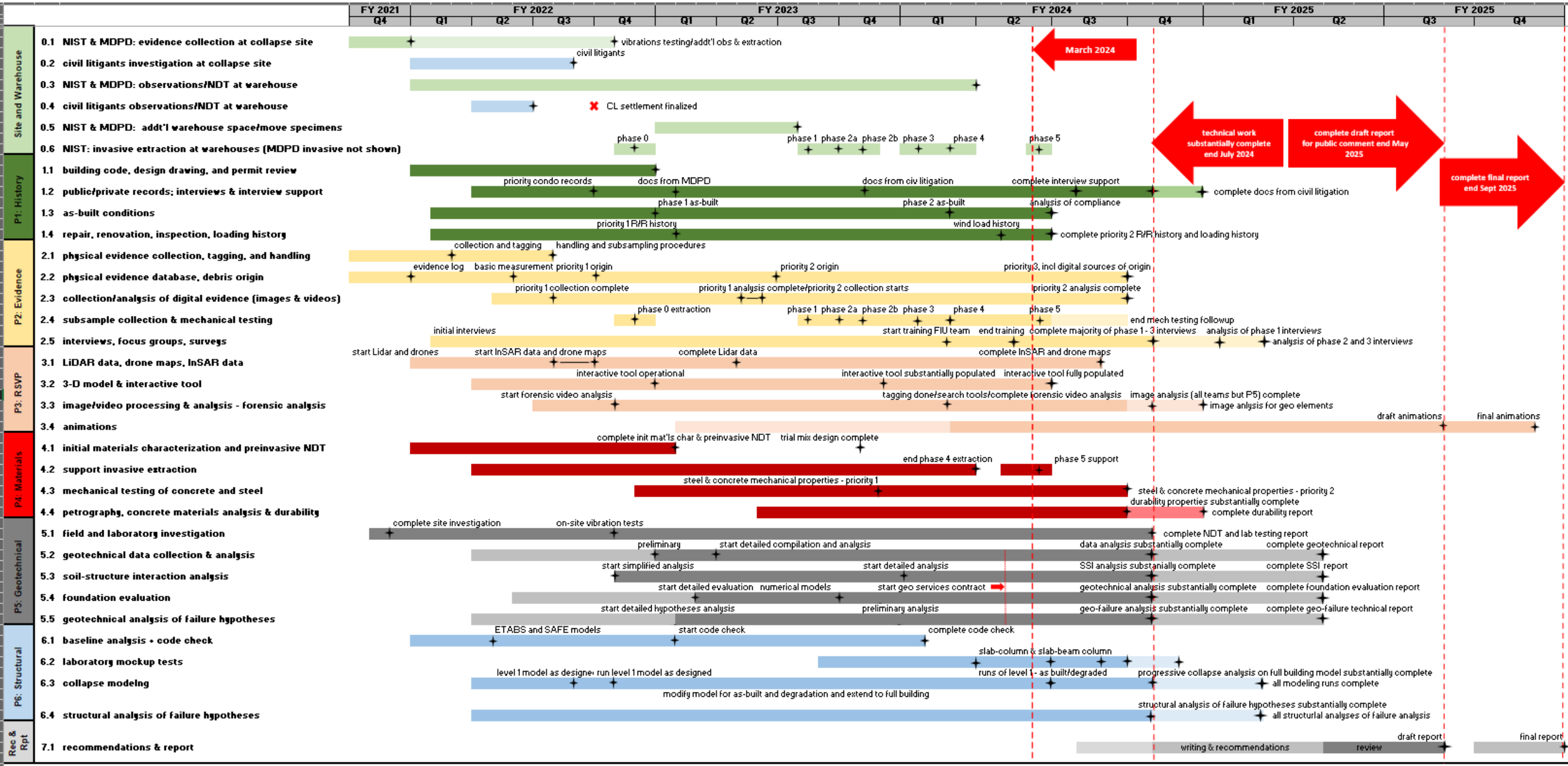
Front Matter (e.g., Table of Contents and Executive Summary)

- Chapter 1** **Genesis of This Investigation**
- Chapter 2** **Investigation Approach and Management**
- Chapter 3** **Champlain Towers South**
- Chapter 4** **Review of Codes and Standards of Practice for Design and Construction**
- Chapter 5** **Post-Collapse Site Investigation**
- Chapter 6** **Social Science**
- Chapter 7** **Timelines**
- Chapter 8** **Physical Evidence**
- Chapter 9** **Testing**
- Chapter 10** **Evidence Analyses**
- Chapter 11** **Materials Analysis**
- Chapter 12** **Geotechnical Analysis**
- Chapter 13** **Structural Analysis**
- Chapter 14** **Evaluation of Failure Hypotheses**
- Chapter 15** **Findings**
- Chapter 16** **Recommendations**

Appendices

Schedule and Six-Month Look Ahead

Investigation Schedule



NEXT SIX MONTHS

Analysis of Failure Hypotheses

Phase 5
Extractions

Substantial completion of
technical work

Document Review
Pre-collapse Conditions

Analysis of Origin and Digital Data
Interviews, Focus Groups, Surveys

Image Analysis

Mechanical Properties of Concrete and Reinforcement
Analysis of Reinforcement Corrosion and Concrete Durability

NIST In-house Geotechnical Analyses
Geo-services Contract

Structural Tests
Collapse Analyses and Simulations

Development of Recommendations

Report Writing, Graphics, Animations

Questions?

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<https://www.nist.gov/champlain>