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THE RESILIENT CITY:
DEFINING WHAT SAN FRANCISCO NEEDS FROM ITS SEISMIC MITIGATION POLICIES

SPUR REPORT

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INTRODUCTION

When a major earthquake strikes the Bay Area, we will face thousands of casualties, hundreds of thousands of displaced households, and losses in the hundreds of billions of dollars. Recovery will take years.

This paper addresses one aspect of the broader policy problem related to making San Francisco resilient in the face of a disaster - the standards we use for deciding when a structure is "safe enough." Our building code embodies hundreds of judgment calls about how strong structures should be, but the public and the policy makers generally have no idea what these standards mean, what the outcomes will be from the "black box" of engineering decisions.

The truth is that when we choose our engineering standards we really are choosing to define how many deaths, how many building demolitions, and how long a recovery time we will have for various levels of earthquakes. Currently, the City of San Francisco has no adopted performance objectives for determining these factors. As a result,

- Design and construction requirements for new construction still focus mostly on preventing the loss of life and in most cases ignore the question of building damage and post-earthquake usability.
- Little is being done to rehabilitate older existing structures, which constitute the majority of buildings and which were built without earthquake-resistant features now required.
- There is no consistent approach to providing, maintaining, and restoring lifeline systems that are needed to support economic recovery.

The overall impact and cost of a disaster is strongly influenced by how long it takes to recover. The time needed to recover depends on the level of damage sustained by buildings, the availability of utilities, and how quickly communities can re-establish usable housing and livable environments.

This paper provides a new framework for improving San Francisco's resilience through seismic mitigation policies. Our goals are to:

a. define the concept of "resilience" in the context of disaster planning,

b. establish performance goals for the "expected" earthquake that supports our definition of resilience,

c. define transparent performance measures that help us reach our performance goals; and

d. suggest next steps for San Francisco's new buildings, existing buildings and lifelines.

A DISASTER RESILIENT SAN FRANCISCO

Whether hit by a massive earthquake or by a hurricane, tornado, flood, or terrorist attack some communities have shown an incredible ability to recover, that is incredible resilience. Resilient communities have an ability to govern after a disaster has struck. These communities adhere to building standards that allow the power, water, and communication networks to begin operating again shortly after a disaster and that allow people to stay in their homes, travel to where they need to be, and resume a fairly normal living routine within weeks. They are able to return to a "new" normal within a few years. They are resilient communities because such a blow from nature remains a disaster, but does not become a catastrophe that defies recovery.

SPUR believes that San Francisco's disaster planning efforts must stem from a clear understanding of resilience. SPUR defines "seismic resilience" as the ability of the city to remain safe and usable after a major earthquake A resilient city is able to contain the effects of earthquakes when they occur, carry out recovery activities in ways that minimize social disruption, and rebuild following earthquakes in ways that mitigate the effects of future earthquakes. San Francisco's current disaster planning efforts are moving in the right direction, but the lack of public knowledge about the current performance of our buildings and lifelines is hindering our ability to become a resilient city. .

Efforts to define the city's seismic resilience objectives must come with a clear and transparent understanding of the hazards and risks that we face. These should be defined in terms of the earthquakes we expect to occur, the damage they will cause to the built environment, and the effects of that damage on response and recovery. What is needed is a set of simple, useful, and expanded performance goals adopted and accepted by policy makers that set reasonable standards for restoring everyday life in the wake of a disaster. The set of general recovery objectives now included in the City and County Emergency Response Plan (Appendix1) is a first good step. SPUR believes that these policies need critical examination and expansion to focus on facilitating recovery.

Achieving a desirable level of disaster resilience requires a clear and specific understanding of what is likely to happen in the wake of an earthquake, and specific ideas for how to improve the performance of facilities in order to meet adopted goals. Commonly held misconceptions of expected seismic performance confuse efforts to improve seismic resilience. For example, the common belief that buildings and infrastructure built to code are "earthquake-proof" is incorrect. Instead, many new facilities are designed today with the expectation (at least by the earthquake professionals) that significant damage likely will occur in a major earthquake. SPUR believes that simple and direct descriptions of seismic performance goals should be adopted so that regulations to achieve these goals can be developed. Recommended goals are summarized below for how building performance should be categorized given the major earthquake that is expected to occur.

PERFORMANCE GOALS FOR THE "EXPECTED" EARTHQUAKE

SPUR is not recommending that all facilities be upgraded to a level that would make them damage proof without regard to cost. Rather, our intent is to clarify the level of damage that is acceptable and require only those improvements in performance needed to assure a quick recovery, or the level of resilience desired. We believe that most of the current criteria for new buildings are adequate, and the need for strengthening existing buildings is perhaps less extensive than generally perceived. Nevertheless, some important changes are needed.

For purposes of this discussion, seismic performance goals are stated in terms of the general states of damage and repair over an extended recovery period under the assumption that an "expected" earthquake has occurred. We chose to analyze the "expected" earthquake, rather than the "extreme" event, because it is a large event that can reasonably be expected to occur once during the useful life of a structure or lifeline system (see section, “Defining the ‘Expected’ Earthquake, below)

We have defined performance goals in terms of three response and recovery phases, four categories or "clusters" of infrastructure types, eight performance categories and selected time frames as shown in the tables below.

TABLE 1: RECOVERY OBJECTIVES BY TIMEFRAME

Phase	Time Frame	Condition of the built environment
1.	1 to 7 days	Initial Response and staging for reconstruction
	Immediate	Mayor proclaims a local emergency and opens the Emergency Operations Center. Hospitals, police stations, fire stations, and City Department Operations Centers are operational.
	Within 4 hours:	People who leave or return to the city in order to get home are able to do so.
	Within 24 hours	Emergency response workers are able to activate and their operations are fully mobilized. Hotels designated to house emergency response workers are safe and usable Shelters are open. All occupied households are inspected by their occupants and less than 5 percent of all dwelling units are found unsafe to be occupied. Residents will shelter in place[1] in superficially damaged buildings even if utility services are not functioning.
	Within 72 hours	Ninety percent of the utility systems (power, water. waste water, and communication systems) are operational and serving the facilities supporting emergency operations and neighborhoods. Ninety percent of the major transportation systems routes, including Bay crossings and airports, are open at least for emergency response. The focus of the initial recovery and reconstruction efforts will be focused on repairing residences, schools and medical provider offices to a usable condition and providing the utilities they need to function. Essential City services are fully restored.
2.	30 to 60 days	Housing restored – ongoing social needs met
	Within 30 days	All utility systems and transportation routes serving neighborhoods are restored to 95 percent of pre-event service levels, public transportation is running at 90 percent capacity, Public schools are open and in session. Ninety percent of the neighborhood businesses are open and serving the workforce.
	Within 60 days	Airports are open for general use, public transportation is running at 95 percent capacity, minor transportation routes are repaired and reopened.
3	Several Years	Long Term Reconstruction
	Within 4	Temporary shelters are closed. All displaced households have returned home or have

1 Shelter in place is used by emergency response professionals to mean the place in a building where people can seek safety during a life threatening incident. SPUR uses "shelter in place" to mean that a building is disaster resilient enough for people to safely remain in their home during both the earthquake itself and subsequent needed repairs, even though the public utility systems may not be working.

	months	permanently relocated. 95 percent of the community retail services are reopened. 50 percent of the non-workforce support businesses are reopened.
	Within 3 years	All business operations, including all City services not related to emergency response or reconstruction, are restored to pre-earthquake levels.

DEFINING THE “EXPECTED” EARTHQUAKE

A defined level of earthquake performance only makes sense if you also define which earthquake you’re talking about. The same damage or disruption that might be forgivable in a large earthquake might be unacceptable in a small one.

Earthquakes are commonly reported in the public press in terms of the Richter Magnitude. That measure was defined in the early 1940s and is useful only for quantifying the energy released overall by a single earthquake. It offers little in terms of how buildings or infrastructure will fare or how they should be designed.

In order to evaluate an existing facility or design a new one, earth scientists and engineers today use different measures to quantify the intensity of the expected shaking at a specific site. These engineering measures account for the possible effects of different earthquakes on multiple faults and therefore are defined in probabilistic terms. For example, a building might be designed for the level of shaking expected to occur with 10% probability over a 50-year time period.

A third way of defining earthquakes involves “scenario events”: – specific hypothetical earthquakes defined by the location of the fault rupture and the magnitude of the energy released. For example, a “magnitude 6.9 earthquake on the San Andreas fault near Santa Cruz” would be one scenario event of possible interest in San Francisco, as that would represent a repeat of the 1989 Loma Prieta earthquake. Scenario earthquakes are especially useful for city-wide or regional planning. They also are easier to grasp than probabilistic measures and are therefore effective for communicating earthquake risk to policy makers and to the public. In 2003, the San Francisco Department of Building Inspection’s Community Action Plan for Seismic Safety chose four scenario earthquakes as the basis for its planning and mitigation programs.

For the purposes of defining resilience and developing mitigation policies to achieve it, SPUR uses one of the scenario earthquakes also used by the Community Action Plan for Seismic Safety and refers to it as the expected earthquake: A magnitude 7.2 earthquake located on the Peninsula segment of the San Andreas fault.

Our expectations, our goals, and our recommendations are presented with this event in mind. This expected earthquake can be expected - conservatively but reasonably to occur once during the useful life of a structure or system, and more frequently if the structure is renovated periodically (as most San Francisco buildings are) to serve more than one or two generations. Of course, this defined scenario would produce different levels of shaking at different locations, but for most of the city, its effects would be similar, in probabilistic terms, to those with a 10 percent chance of occurring over a 50-year period.

We define resilience in terms of this expected earthquake. Other earthquakes are possible, of course. In a smaller, more routine earthquake, better performance would be expected. For a larger, more extreme event, lesser performance would have to be tolerated. All three events are defined below to encourage uniform definitions.

TABLE 2: EARTHQUAKE LEVELS DEFINED

Routine	Earthquakes that are likely to occur routinely. Routine earthquakes are defined as having a 70 percent probability of occurring in 50 years. In general, earthquakes of this size will have magnitudes equal to 5.0 - 5.5, should not cause any noticeable damage, and should only serve as a reminder of the inevitable. San Francisco's Department of Building Inspection (DBI) uses this earthquake level in their Administrative Bulletin AB 083 for purposes of defining the "service level" performance of tall buildings.
Expected	An earthquake that can reasonably be expected to occur once during the useful life of a structure or system. It is defined as having a 10 percent probability of occurrence in 50 years. San Francisco's Community Action Plan for Seismic Safety (CAPSS) assumed that a magnitude 7.2 earthquake located on the peninsula segment of the San Andreas Fault would produce this level of shaking in most of the City. Because structures can last for hundreds of years, but typically need to be refurbished every 30 to 50 years, a 50- year period is appropriate. Creating a resilient San Francisco based on this expected shaking intensity, associated with this size of earthquake is a practical and prudent basis for public policy.
Extreme (Maximum Considered Earthquake)	The extreme earthquake that can reasonably be expected to occur on a nearby fault. It is defined as having a 2 percent probability of occurrence in 50 years. The CAPSS defined magnitude 7.9 earthquake located on the peninsula segment of the San Andreas Fault would produce this level of shaking in most of the city.

DEFINING TRANSPARENT PERFORMANCE MEASURES

Declaring in simple, concise and understandable terms the expected seismic performance of structures and systems given a specific earthquake size requires first the adoption of terms that are recognizable, consistent with other performance rating systems, and useful is establishing policy. While the earthquake professional community has learned that expected seismic performance is best measured and expressed in terms of casualties (lives lost and serious injuries), dollar loss (cost of repair as a percentage of replacement value), and the length of time required to repair for reuse or restore service, no standard set of performance measures is in use.

The various engineering professions use a wide variety of terms to describe their performance expectations and, in some cases, do not clearly state what they are. In the case of new buildings, the code requires different design standards for essential facilities, high occupancy facilities, and facilities containing hazardous materials, but stops short of declaring what performance is expected. Rehabilitation standards for existing buildings that are undergoing refurbishment are often designed to an explicit performance level but many voluntary retrofits are done to no specific standard. Utility systems are often designed with employee safety goals and expected days to restore service to users, though there is no consistency.

Most important, even when performance objectives are explicitly defined, they are almost always stated in terms of safety only – that is, in terms of whether people nearby would be injured during the earthquake itself. While safety is essential, this limited perspective fails to address the larger questions of resilience: Will the buildings be usable when the shaking stops, and how soon will full services be restored?

For purposes of understanding and working toward resilience, SPUR defines categories of the expected performance of buildings and lifeline systems in terms of *both* safety during the earthquake and usability during the response and recovery periods that follow. Lifeline performance is further defined in terms of the time allowed to resume service.

SPUR uses the following terms in developing new building design standards and mitigation programs needed to achieve San Francisco's resilience objectives. The levels of performance they describe are to be paired with the effects of the Expected earthquake. Table 3 presents these performance measures in a tabular form.

TABLE 3: SEISMIC PERFORMANCE MEASURES FOR BUILDINGS

Category A:	Safe and Operational. This describes the performance now expected of new essential facilities such as hospitals and emergency operations centers. Buildings will experience only very minor damage and have energy, water, wastewater, and telecommunications systems to back-up any disruption to the normal utility services.
Category B:	Safe and usable during repair. This describes the performance needed for buildings that will be used to shelter in place and for some emergency operations. Buildings will experience damage and disruption to their utility services, but no significant damage to the structural system. They may be occupied without restriction and are expected to receive a green tag1 after the "expected" earthquake.
Category C:	Safe and usable after repair. This describes the current expectation for new, non-essential buildings. Buildings may experience significant structural damage that will require repairs prior to resuming unrestricted occupancy and therefore are expected to receive a yellow tag2 after the "expected" earthquake. Time required for repair will likely vary from four months to three years or more.
Category D:	Safe but not Repairable. This level of performance represents the low end of acceptability for new, non-essential buildings, and is often used as a performance goal for existing buildings undergoing rehabilitation. Buildings may experience extensive structural damage and may be near collapse. Even if repair is technically feasible, it might not be financially justifiable. Many buildings performing at this level are expected to receive a red tag3 after the "expected" earthquake.
Category E:	Unsafe: Partial or complete collapse. Damage that will likely lead to significant casualties in the event of an "expected" earthquake. These are the "killer" buildings that need to be addressed most urgently by new mitigation policies.

In addition, SPUR defines the expected performance of all utility and transportation systems, or portions of systems, serving the City in terms of the days required to restore service to 90 percent, 95 percent and 100 percent of the defined customer base.

Category I-Resume 100 percent of service levels within four hours.

Critical response facilities - including emergency housing centers – need to be supported by utility and transportation systems critical to their success. This level of performance assures that these systems will be available within four hours of the disaster. It requires a combination of well built buildings and systems, provisions for making immediate repairs as needed, and redundancy within the networks that allows troubled spots to be isolated.

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[1] Building inspected and deemed safe for occupancy.
[2] Building inspected and found to be damaged enough to warrant restricted access.
[3] Building inspected and found to be unsafe to occupy.

Category II--Resume 90 percent service within 72 hours, 95 percent within 30 days, 100 percent within four months

Housing and residential neighborhoods require utility and transportation systems be restored quickly so that these areas can brought back to livable conditions. There is time to make repairs to lightly damaged buildings and replace isolated portions of the networks or create alternate paths for bridging around the damage. There is time for parts and materials needed for repairs to be imported into damaged areas. These systems need to have a higher level of resilience and redundancy than the systems that support the rest of the city.

Category III-Resume 90 percent of service within 72 hours, 95 percent within 30 days, 100 percent within three years

The balance of the city needs to have it's systems restored as buildings are repaired and returned to operation. There is time to repair and replace older vulnerable systems with new. Temporary systems can be installed as needed. Most existing lifeline systems will qualify for Category III performance.

TABLE 4: DEFINING RESILIENCE FOR SAN FRANCISCO

As mentioned above, SPUR defines San Francisco's "seismic resilience" as its ability to contain the effects of earthquakes when they occur, carry out recovery activities in ways that minimize social disruption, and rebuild following earthquakes in ways that mitigate the effects of future earthquakes. This chart represents our best thinking as to how a resilient San Francisco ought to perform in the event of an expected earthquake, and how far away we are right now from meeting that goal.

TARGET STATES OF RECOVERY FOR SAN FRANCISCO'S BUILDINGS AND INFRASTRUCTURE

INFRASTRUCTURE CLUSTER FACILITIES	Event occurs	Phase 1 Hours			Phase 2 Days		Phase 3 Months		
		4	24	72	30	60	4	36	36+
CRITICAL RESPONSE FACILITIES AND SUPPORT SYSTEMS									
Hospitals	A							X	
Police and fire stations	A		X						
Emergency Operations Center	A								
Related utilities		B				X			
Roads and ports for emergency		B		X					
CalTrain for emergency traffic				B	X				
Airport for emergency traffic				B, X					
EMERGENCY HOUSING AND SUPPORT SYSTEMS									
95% residence shelter-in-place			B					X	
Emergency responder housing			B	X					
Public shelters			B				X		
90% related utilities				C				X	
90% roads, port facilities and public transit				C			X		
90% Muni and BART capacity				C		X			
HOUSING AND NEIGBORHOOD INFRASTRUCTURE									
Essential city service facilities					C		X		
Schools					C		X		
Medical provider offices					C			X	
90% reighborhood retail services					C				X
95% of all utilities					C			X	
90% roads and highways					C	X			
90% transit					C	X			
90% railroads					C		X		
Airport for commercial traffic					C, X				
95% transit						C	X		
COMMUNITY RECOVERY									
All residences repaired, replaced or relocated							C		X
95% neighboorhood retail businesses open							C	X	
50% offices and workplaces open							C		X
Non-emergency city service facilities								C, X	
All businesses open								C	X
100% utilities								C	X
100% roads and highways								C	X
100% travel								C	X

Source: SPUR analysis

TARGET STATES OF RECOVERY

Performance measure	Description of usability after expected event: BUILDINGS	LIFELINES
A (light shading)	Category A: Safe and operational	
B (medium shading)	Category B: Safe and usable during repairs	100% restored in 4 hours
C (dark shading)	Category C: Safe and usable after moderate repairs	100% restored in 4 months
X	Expected current status	

NEXT STEPS

While this paper defines the goal of a earthquake-resilient San Francisco, new papers on new buildings, existing buildings, and lifelines recommend actions to achieve this goal. Overall SPUR's specific recommendations for action have been developed by considering:

(1) the goals for seismic resilience for each component of our city

(2) the gap between current seismic performance and the goal, and

(3) the cost of making the necessary improvements or retrofits.

Priority is given to those actions that provide the best improvement to seismic performance and resilience with the least amount of cost and disruption.

SPUR's recommendations[4] for existing buildings focus on dealing with the city's most seriously deficient buildings through mandatory programs where the needs are clear, and the development of additional programs where further definition is needed. Soft story wood frame buildings need to be retrofitted. Buildings providing shelter and other essential City services need to be evaluated and retrofitted as needed. San Francisco's non-ductile concrete buildings – structures that have frames of steel reinforced concrete, as differentiated from the typically brick built unreinforced masonry buildings, and that are vulnerable because their frames do not bend in earthquakes – need to be inventoried, and a program should be developed to mitigate their potential for collapse. Gas shut off valves need to be installed to prevent massive fires from consuming the city following an earthquake. And the adequacy of the 1992 Unreinforced Masonry Building Retrofit Ordinance needs to be assessed.

SPUR's recommendations for new buildings focus on adding transparency to the building code requirements; incorporating new, near term cost-effective improvements into the code; creating a certification system for voluntary seismic upgrades akin to the LEED system for green building standards; and adding strong incentives for owners to build to higher seismic standards. Owners and tenants need to understand what seismic performance to expect from the buildings they own, lease and construct, and the options they have for improvement.

SPUR's recommendations for lifelines begin with the formation of a lifelines council that brings the various owners and operators together to assess the vulnerability of the systems that serve San Francisco. The council also should develop performance standards and retrofit priorities. The City needs to incorporate the needed retrofits into its capital improvement plans, give specific attention to managing the city's gas system, and form partnerships with the regional and state public and private providers to secure the necessary modifications to their systems. The City also should become an advocate at all levels for the development of consistent performance standards nationwide.

Achieving disaster resilience is critical to the survival of San Francisco. Resiliency is not an impossible nor economically infeasible goal. Success requires a clear understanding of what will happen, and what steps must be taken now – before the disaster - coupled with an achievable implementation schedule and a rational program of incentives to make programs feasible. These recommended first steps serve to bring clarity and transparency to the problems we face, and set the stage for the development of detailed solutions.

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[4] The following paragraphs summarize the policy recommendations of SPUR's three other "Before the Disaster" policy papers: "The Dilemma of Existing Buildings: Private Ownership, Public Risk," "Building it Right the First Time: Improving the Seismic Performance of New Buildings," and "Upgrading Infrastructure to Enhance San Francisco's Earthquake Resilience." All three papers can be found on SPUR's website at www.SPUR.org.

SPUR believes that we must embark on what will likely be a 50-year process to make San Francisco a resilient city. The recommendations within this paper help us get started.

APPENDIX ONE

San Francisco has maintained workable and exercised emergency operations plans for decades. The CCSF 2005 Emergency Operations Plan represents the latest complete document that outlines the organizational structure and operating procedures that are placed in effect in the event of a major earthquake. That plan is presently undergoing a complete revision and transformation into an all hazards, Emergency Response Plan.

At present, the CCSF 2005 Emergency Operations Plan – Earthquake Response Plan Enhancement includes the follow general objectives and time frames that have been used as a basis for the Resilient City recommendations.

GENERAL OBJECTIVES FOR RESPONSE OPERATIONS

Immediately following a major earthquake, and for as long as a state of emergency exists within the CCSF, the response to the earthquake will be the first priority of all CCSF departments and agencies. All available resources will be directed to achieving the following objectives:

- Save lives.
- Reduce immediate threats to life, public health and safety, and public and private property.
- Provide necessary care, shelter, and medical services to CCSF residents and other members of the general public.
- Restore the operations of facilities, whether public or privately owned, that are essential to health, safety, and welfare of the community, including critical CCSF facilities, hospitals, utilities, and transportation infrastructure.
- Assess damage to infrastructure, public facilities, and the built environment.
- Expedite the restoration of services, the economy, and the community at large; and begin the process of recovery.
- Keep the public informed.