Questions

1. What drove the decision for dropping the bomb on Hiroshima?

2. Who were the observer scientists on the plane?

3. Considering that the Hiroshima attack set a historic precedence, do you think that Hiroshima should/could have been avoided?
Nagasaki
Why drop a second bomb?

Why drop the second bomb at all? Hiroshima has been justified as a way to save the lives that an invasion of Japan would cause. It has been explained as a way to impress the Russians and ensure American superiority in Asia.

By August 1945 the Japanese were all but defeated. The Soviet declaration of war was scheduled for August 15. Truman wrote in his diary about this event, "When this happens, Fini Japs."

On August 9, 1945 the Japanese were reeling from the effects of the bomb on Hiroshima. Their surrender was inevitable before the 15th.

**Why drop a second bomb?**

Is it revenge for Pearl Harbor or is the only reason that:

the Americans had two bombs?

"When you have to deal with a beast you have to treat him as a beast."
—President Harry S. Truman, August 1945

"Now is the time to exterminate the Yellow Peril for all time… Let the rats squeal."
—Congressman Charles A. Plumley, August 1945
Why Nagasaki?

Nagasaki was at the bottom of the pre-identified list of the Target Committee, weather conditions dictated the choice. On the second target list, it was second choice after Kokura.

The reason for being on the target list at all was a concern for psychological effect. Nagasaki was added shortly before the first mission as the last on the list of alternate targets. Kyoto was considered to be the first choice because of its history, as the ancient capital, and "the advantage of the people being more highly intelligent and hence better able to appreciate the significance of the weapon."

These factors were present in Nagasaki as well. The city had been an ancient center of trade with foreign countries, first with China, Vietnam and south Asia. Later when trade with the outside world was cut off, Nagasaki remained a Portuguese and Dutch outpost. Nagasaki was a religious center for Catholicism as well as Buddhism. As a result literacy was high. In addition it held vital war related industry, being the home of the Mitsubishi Aircraft plant and the Ohashi Arms factory.
The old Nagasaki

Old trading center founded by the Portuguese in the 16th century on the site of a Japanese village in the south of the Japanese Isles. Very mountainous region with narrow harbor inlet, later site of a Dutch enclave Dejima during the period when the country was closed to foreign access in 1641–1853. In 19th century site of the early Japanese naval training academy.
The topography of Nagasaki made it an ideal site for testing the shock front behavior and shock reflection adding a new parameter to the impact analysis of a nuclear blast. The target point was chosen to be right in the center of a valley, site of the suburban town Urakami slightly above the actual city center. Mountains reflect a shock, valleys channel the shock in certain directions!
Shock Front Analysis

Decline of shock intensity with time and distance

Variation of overpressure in air with distance at successive times.

Variation of overpressure with time at a point above the surface in the region of regular reflection.
Shock Enhancement & Channeling

Multiple shock bouncing is possible, causing considerable enhancement of the initial destructive power of explosion.
Nagasaki

“Fat Man” detonates over Nagasaki
August 9, 1945
On August 9, 1945 at 9:44 a.m. “Bockscar”, a B-29 plane carrying Fat Man, the world’s third atomic bomb, arrives at its primary target, Kokura. The city is covered in haze and... 74,000 people died immediately. 10,000 Catholics died since target was suburb Urakami, a center of Japanese Catholicism.
Report of the Pilot
The effects of the blast
Urakami Cathedral was the largest church in the entire Orient. The Urakami parish counted 14,000 members.

Battered religious figures stand watch on a hill above a tattered valley

Nagasaki, Japan
September 24, 1945

Uarakami Cathedral was the largest church in the entire Orient. The Urakami parish counted 14,000 members.
Destruction
<table>
<thead>
<tr>
<th>Distance from Ground Zero (km)</th>
<th>Killed</th>
<th>Injured</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 1.0</td>
<td>88%</td>
<td>6%</td>
<td>30,900</td>
</tr>
<tr>
<td>1.0 - 2.5</td>
<td>34%</td>
<td>29%</td>
<td>144,800</td>
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<tr>
<td>2.5 - 5.0</td>
<td>11%</td>
<td>10%</td>
<td>115,200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22%</strong></td>
<td><strong>12%</strong></td>
<td><strong>173,800</strong></td>
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</tbody>
</table>
**Shock emergence**

Friedländer formula for the time dependence of pressure in a transversing shock at a fixed location with respect to shock origin

\[ p(t) = p_r \cdot e^{t/t^*} \cdot \left(1 - \frac{t}{t^*}\right) \]

Taylor equation, derived phenomenological from observation of Trinity fireball expansion. \( W \) is the released energy at distance \( r \) and time \( t \) with air density \( \rho \) and specific heat ratio of air \( \gamma \)
Fat Man had an explosive power of $W=22kT$

$$W = \left( \frac{\rho}{t^2} \right) \left( \frac{r}{\gamma} \right)^5$$

$$r = \gamma \cdot \left( \frac{W \cdot t^2}{\rho} \right)^{1/5} = 1.4 \cdot \left( \frac{22kTon \cdot 1s^2}{1.2kg/m^3} \right)^{1/5} = 1.4 \cdot \left( \frac{22 \cdot 4.184 \cdot 10^{12} kg \frac{m^2}{s^2} \cdot 1s^2}{1.2kg/m^3} \right)^{1/5} \approx 840 m$$

Definition: 1 ton of TNT = 4.184 x 10^9 joule (J).

With a typical air density of $\rho \approx 1.2 \text{ kg/m}^3$ and a typical $\gamma \approx 1.4$ the shock front expands in 1 s by $r \approx 840 \text{ m}$
Nagasaki spreads over area of $\sim 10 \text{km}^2 \approx 4 \text{sqm}$ its destruction was a matter of a couple of seconds.
# Pressure Units

Pressure is defined as: force/area and is the main source of mechanical destruction of buildings and other human structures.

<table>
<thead>
<tr>
<th>Pressure units</th>
</tr>
</thead>
<tbody>
<tr>
<td>V pascal</td>
</tr>
<tr>
<td>1 Pa</td>
</tr>
<tr>
<td>1 bar</td>
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<tr>
<td>1 at</td>
</tr>
<tr>
<td>1 atm</td>
</tr>
<tr>
<td>1 Torr</td>
</tr>
<tr>
<td>1 psi</td>
</tr>
</tbody>
</table>
Shock Velocities

\[ U = c_0 \cdot \left(1 + \frac{\gamma + 1}{2\gamma} \cdot \frac{p}{p_0}\right)^{1/2} \]

pressure is defined as: force/area

\[ U: \text{shock velocity} \]
\[ c_0: \text{speed of sound } c_0 \approx 343 \text{ m/s} \]
\[ \gamma: \text{ratio of specific heat in transporting medium, } \gamma_{\text{air}} \approx 1.4 \]
\[ p: \text{peak overpressure} \]
\[ p_0: \text{ambient pressure ahead of shock (air pressure: } p_0 \approx 1\text{ atm)} \]

for a peak over pressure of \( p \approx 20 \text{ atm}, \) the shock front velocity is \( U \approx 1461 \text{ m/s}, \) that is a supersonic shock, reaching you before you can hear the blast!
Destruction Analysis

with distance from ground zero
Between triumph and revenge feelings

The TRUE STORY OF ALADDIN

WHAT WOULDST THOU HAVE?
I AM READY TO OBEY THEE
AS THY SLAVE.

THE JINNI OF
ATOMIC
POWER

AMERICAN GENIUS
AND THE
MAGIC ELECTRON

THE FELLOW WHO LIGHTED THE FUSE

SO SORRY!

CATACLYSMIC ATOMIC BOMB

JAP SNEAK ATTACK
PEARL HARBOR 1941
Japan’s Unconditional Surrender

September 2, 1945
On board of battleship Missouri in Tokyo Bay
Gen. MacArthur referred to the nuclear bomb attacks on Hiroshima and Nagasaki, saying they had "revised the traditional concept of war".