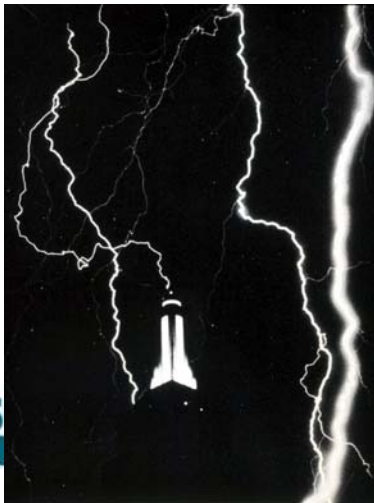


Lightning Attraction of an Elevated Building

G rard BERGER (CNRS), Sonia A T-AMAR (ABB)

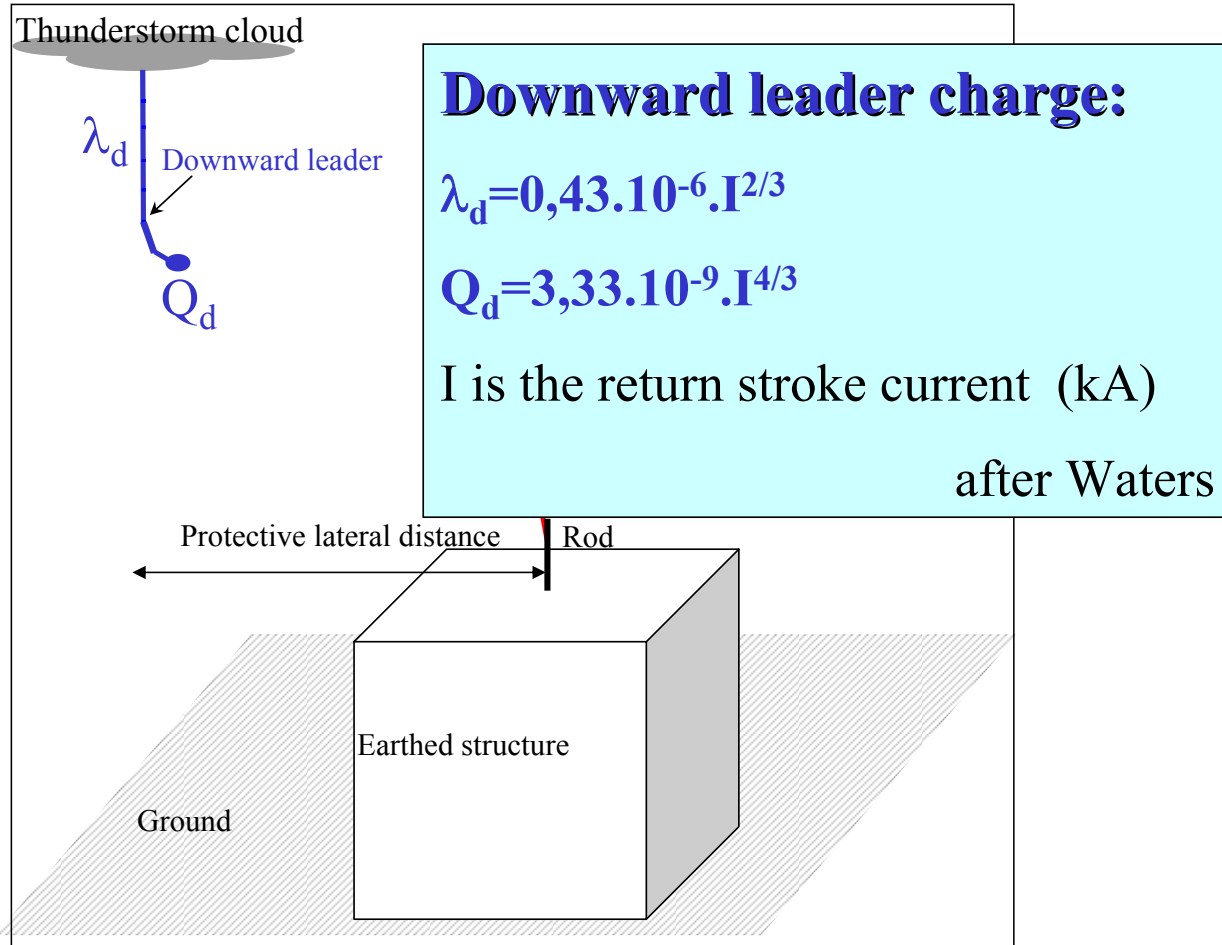


Outline of this presentation

1. Lightning and elevated structures
2. Summary of our interception model
3. Results for :
 - Flat ground
 - Elevated building
4. Conclusions

Original pictures by courtesy of Alex HERMANT



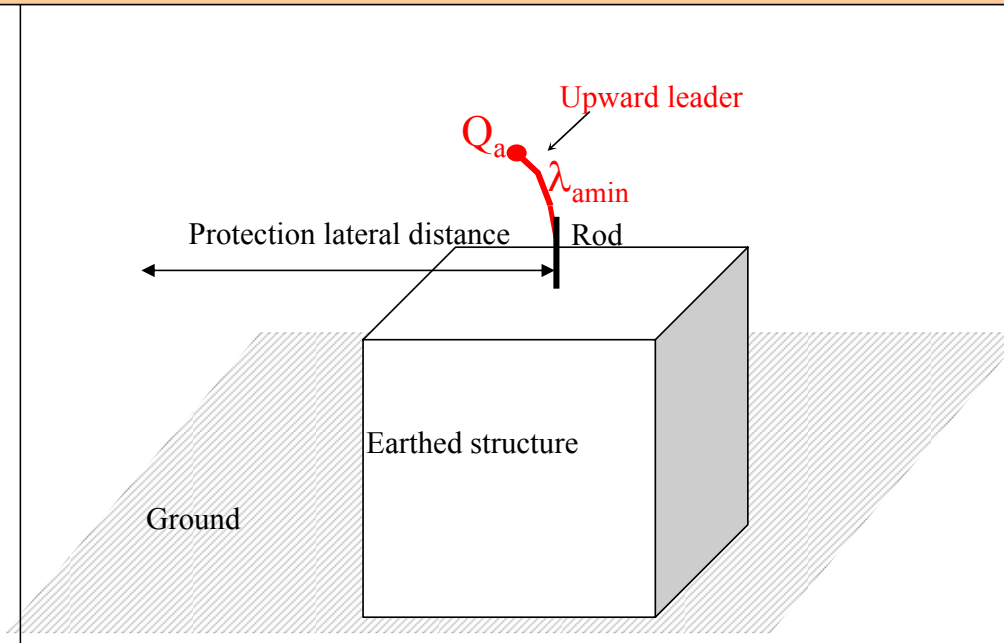


An illustration of downward and upward leaders

Upward leader charge:

$Q_a = \lambda_{amin} / (2 \cdot \pi \cdot \epsilon_0 \cdot E_s)$ $\lambda_{amin} = 50 \mu\text{C/m}$ is the minimum line charge sufficient to maintain the leader propagation stability.

$E_s = 5 \text{ kV/cm}$ is the propagation field of the positive streamer.



An illustration of downward and upward leaders

The velocity ratio R_v

$$R_v = \frac{\text{The downward leader velocity}}{\text{The upward leader velocity}} = \frac{V_{\text{down}}}{V_{\text{up}}}$$

In reality, this ratio should not be treated as a constant. Indeed, the upward leader propagates in an increasing electric field, due to the approach of the downward leader.

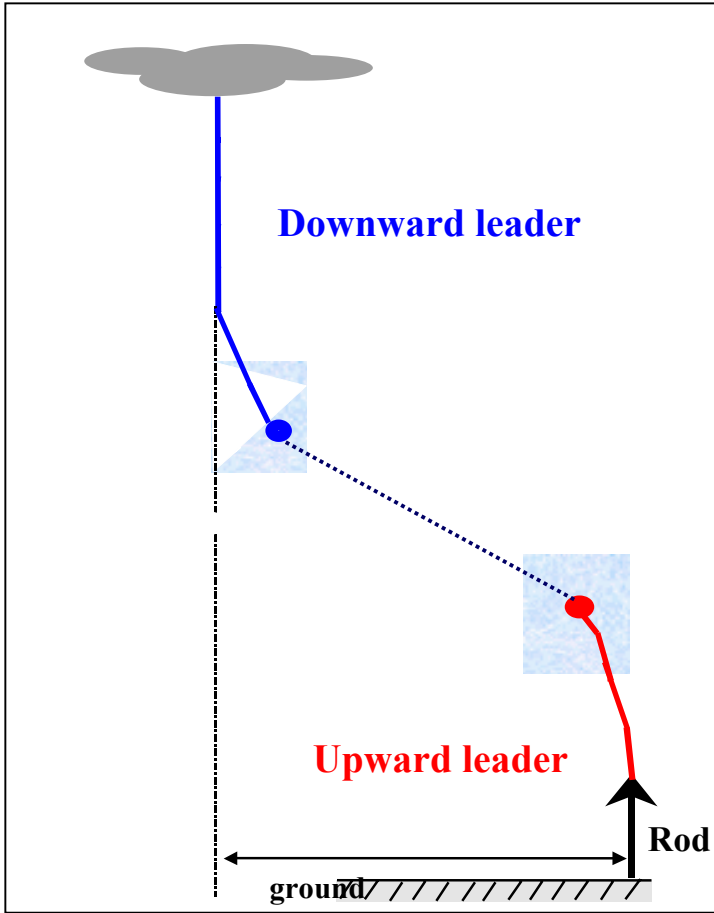
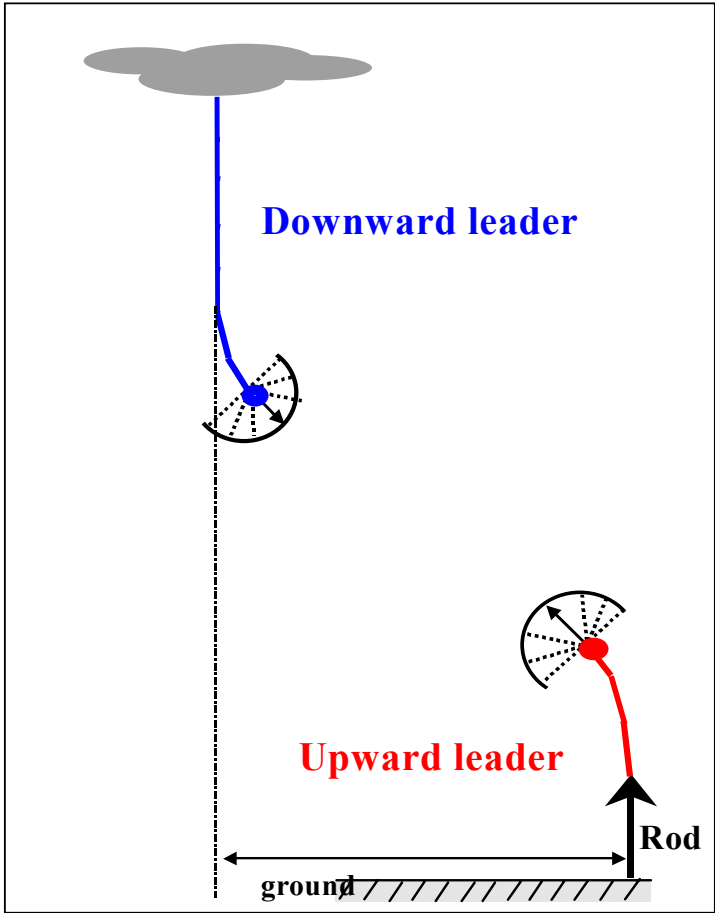


We choose for R_v a range of values from 0.5 to 4.

Conditions for a successful interception

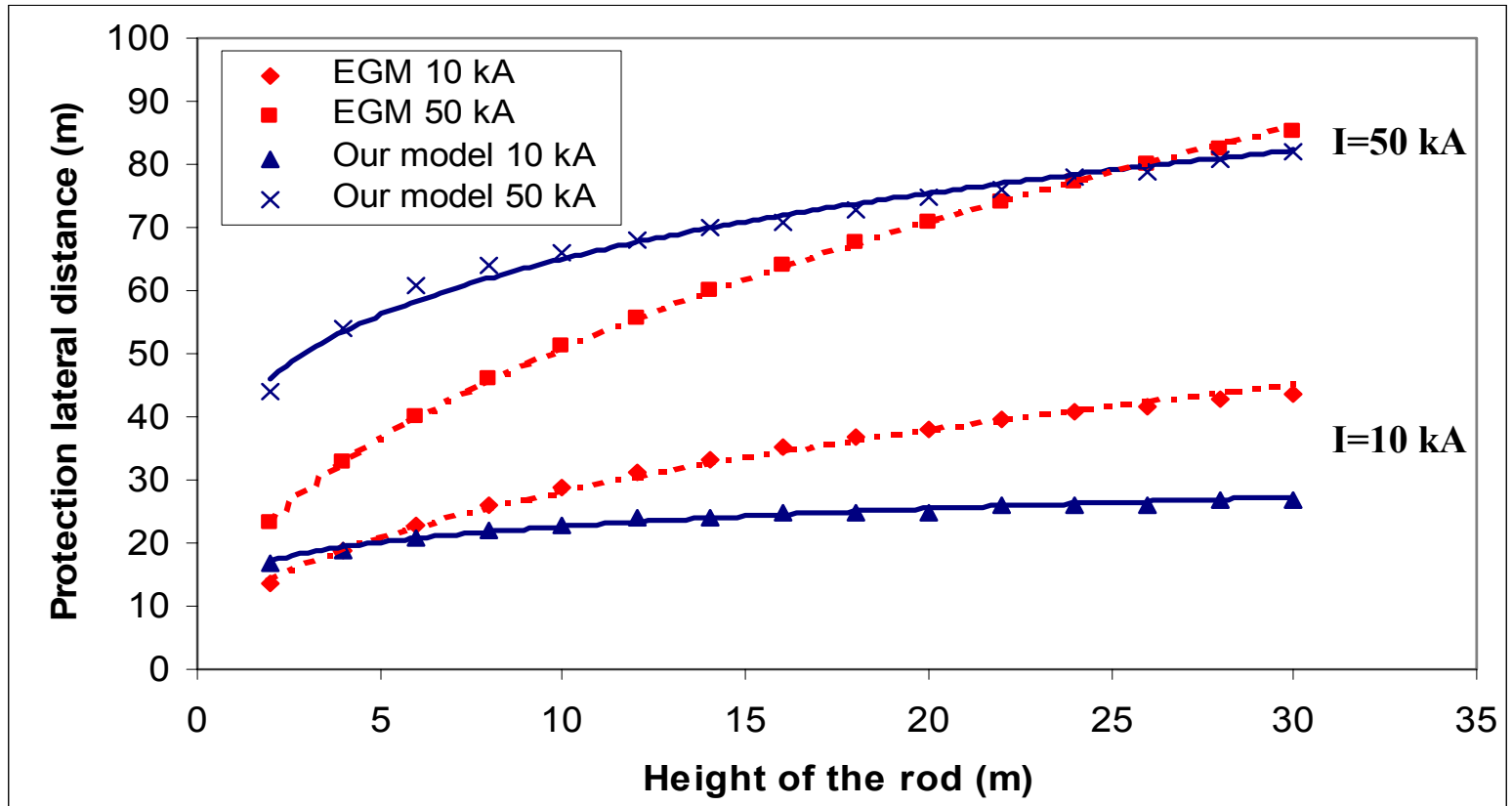
A successful capture by a Franklin rod needs three conditions to be fulfilled:

- **Formation of an upward leader at the tip of the Franklin rod.**
- **Stable propagation of the upward leader**
- **Final junction of the downward and upward leaders.**



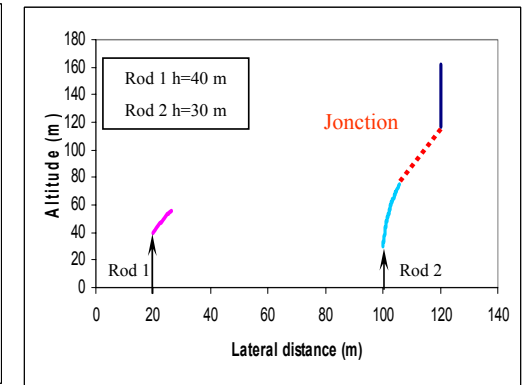
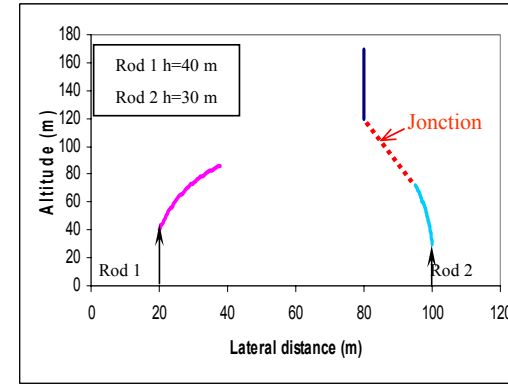
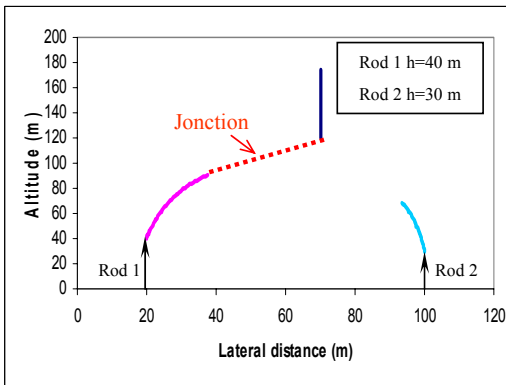
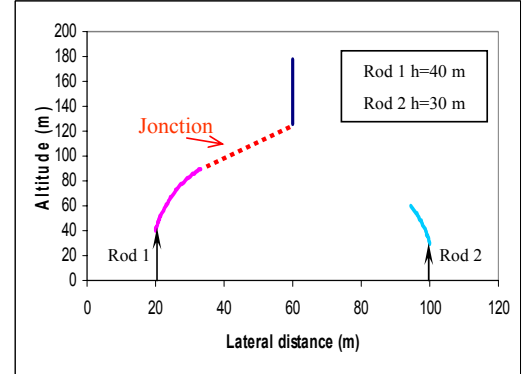
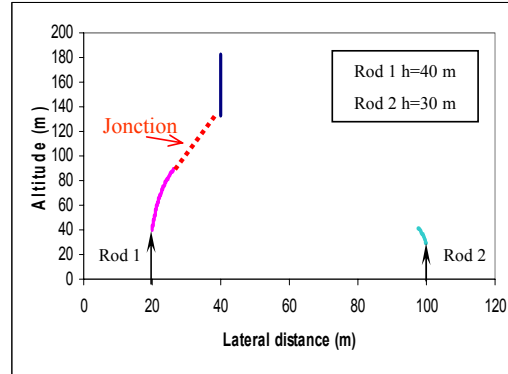
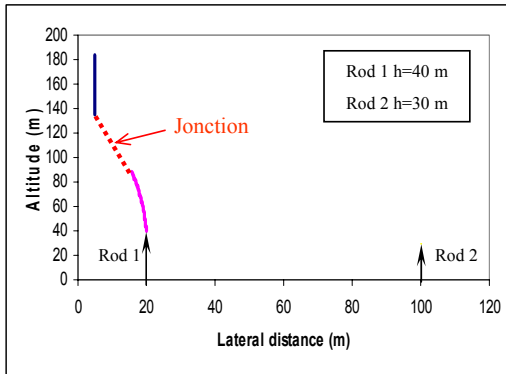
FRANKLIN ROD ON A FLAT GROUND

The case of an unique Franklin rod on a flat ground

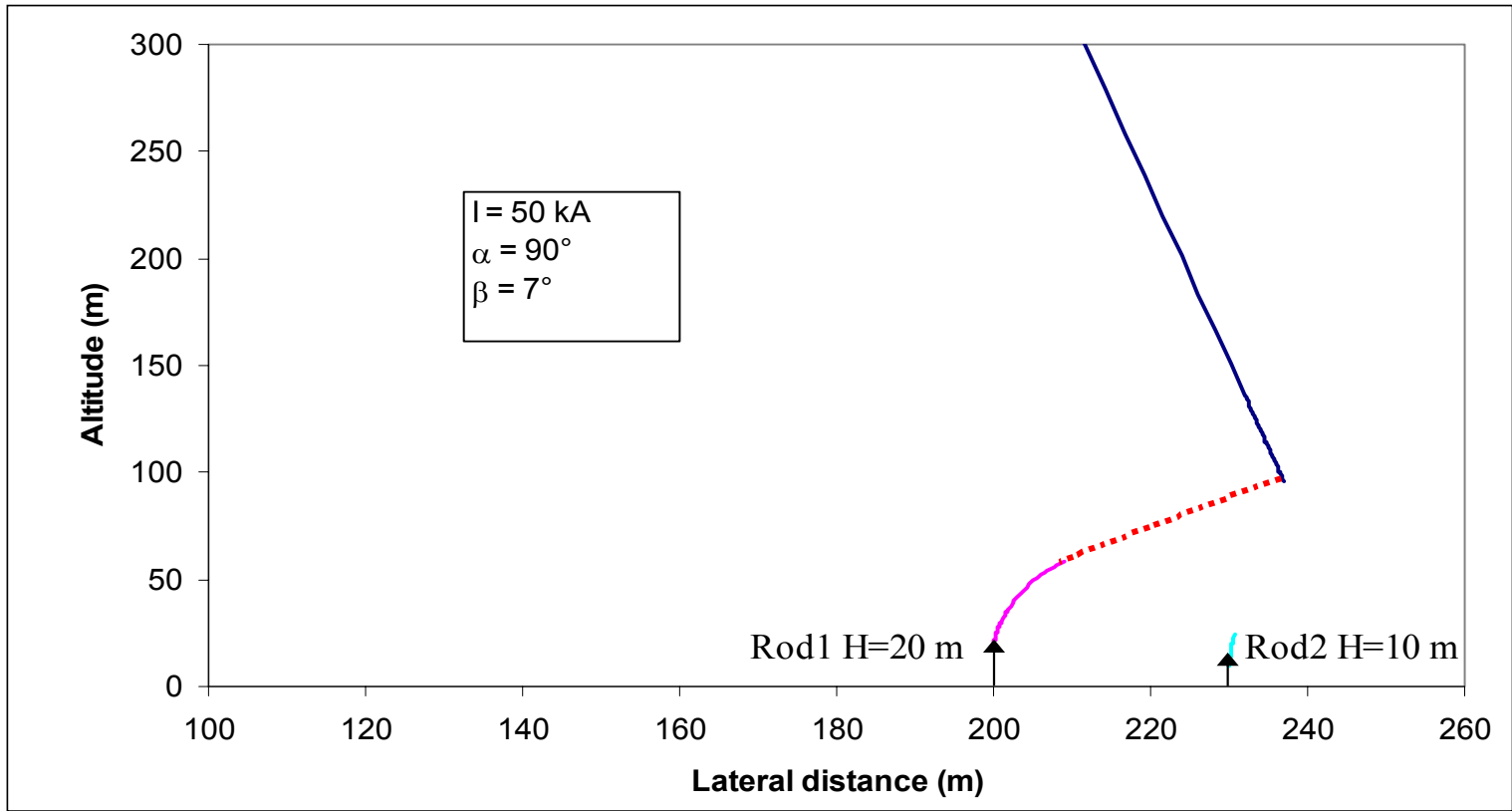


Comparison between the lateral distance of the protections derived from our model and from the electrogeometrical model. $R_v=1$





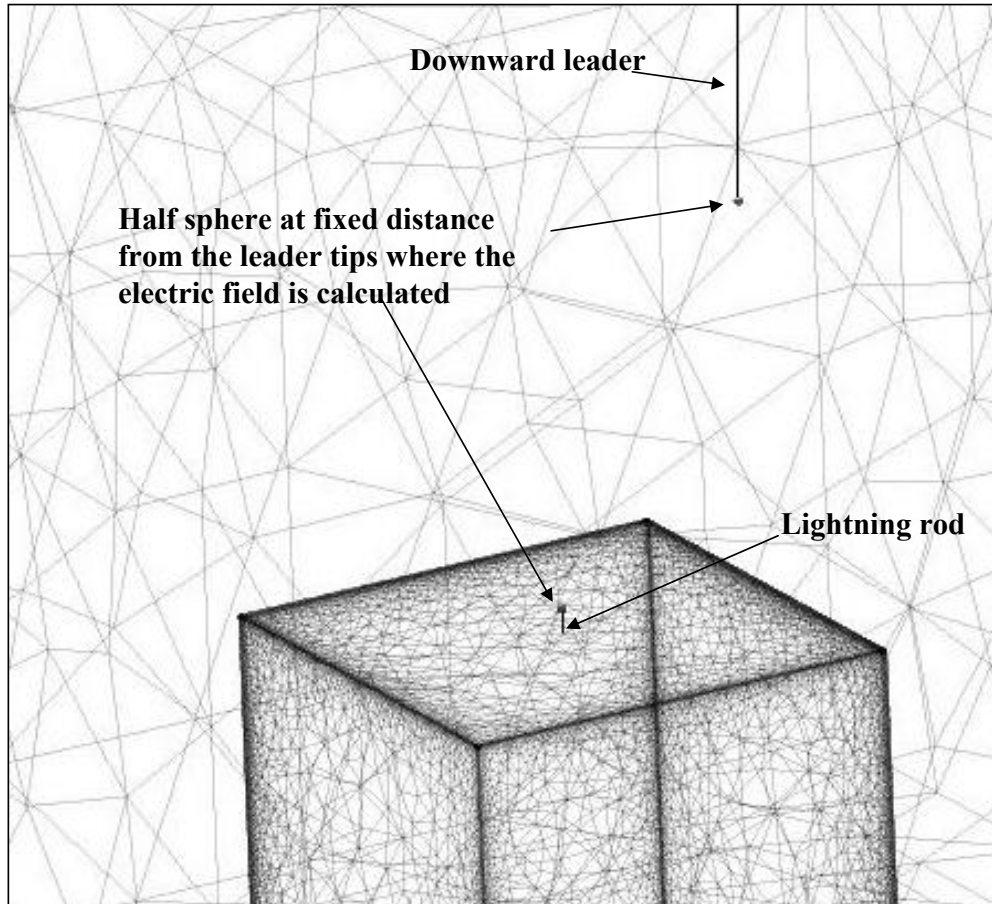
An illustration of the behaviour of two competing rods. $I = 50 \text{ kA}$, $R_v = 1$.



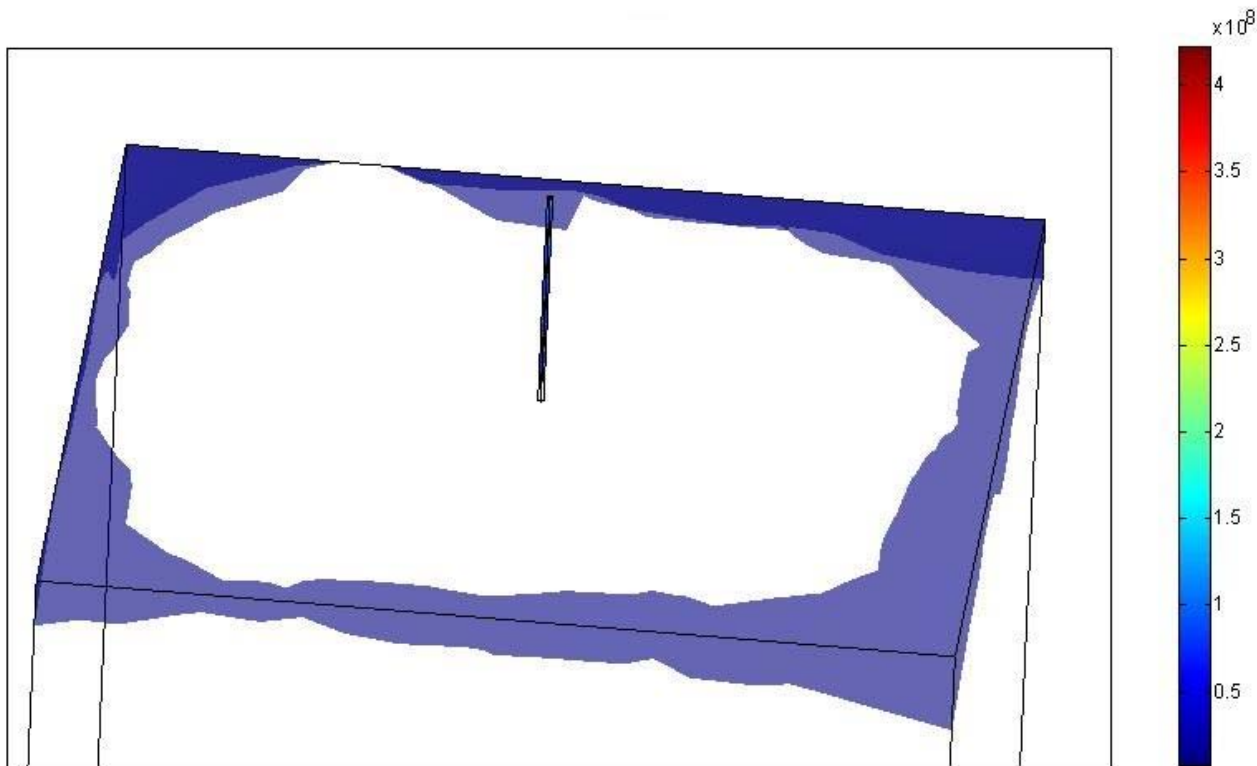
An example of an oblique downward leader. The downward leader trajectory forms an angle α with the X axis and β with the Z axis.

Junction with the rod 1. $I=50 \text{ kA}$, $R_v=1$.

FRANKLIN ROD ON A TALL BUILDING

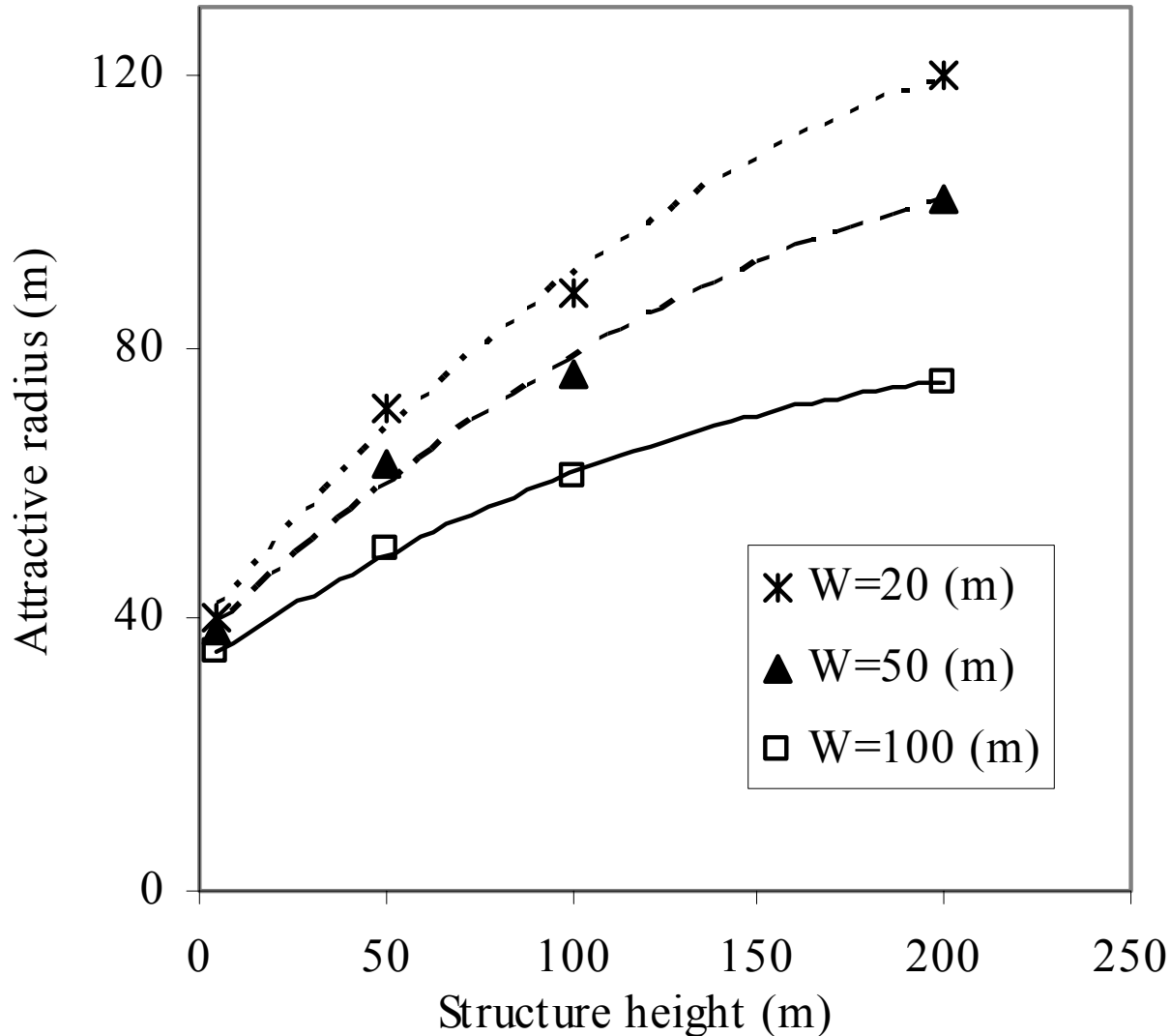


A 3D visualisation of the used meshes

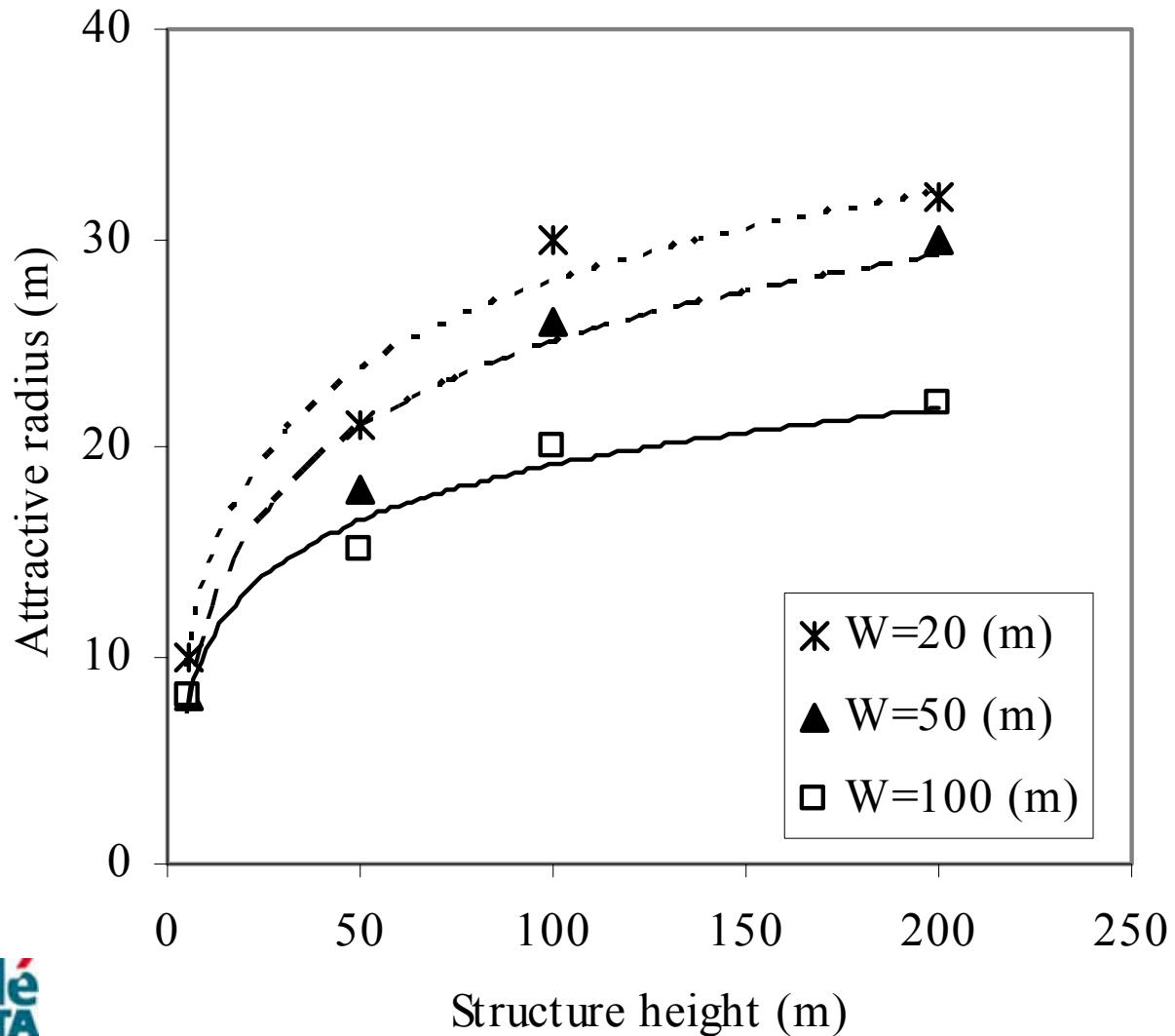


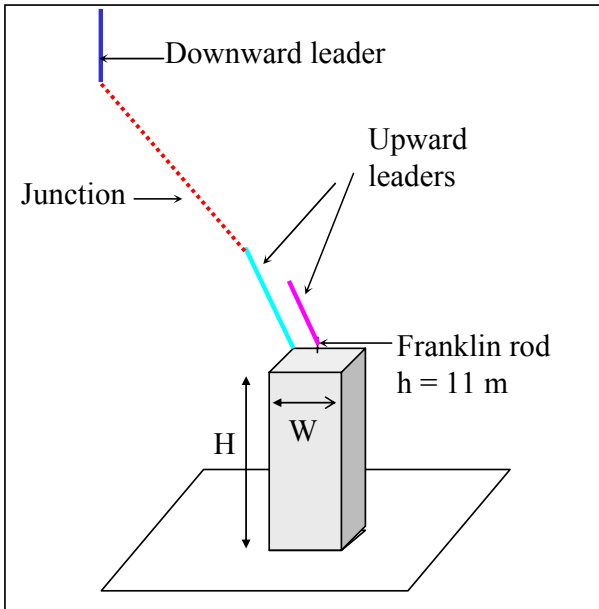
Electric field distribution on a protected structure during a thunderstorm

Attractive radius of corners

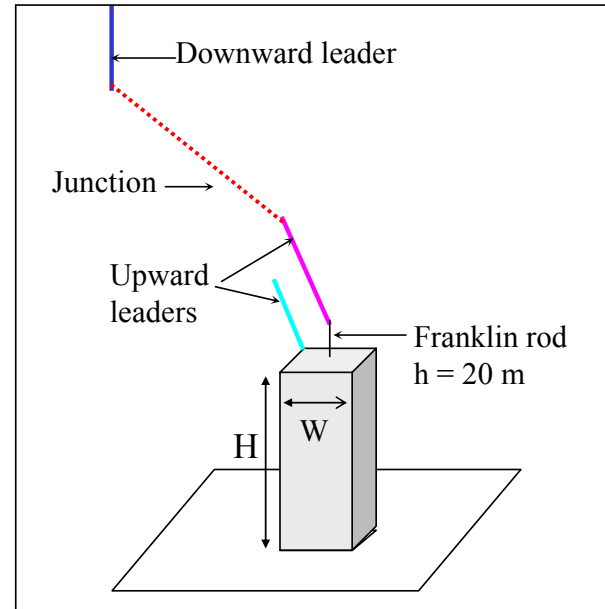


Attractive radius of edges

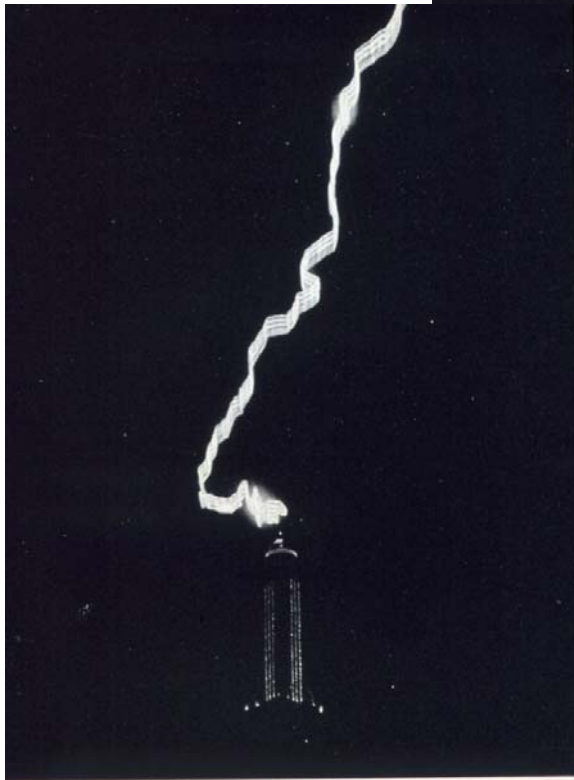




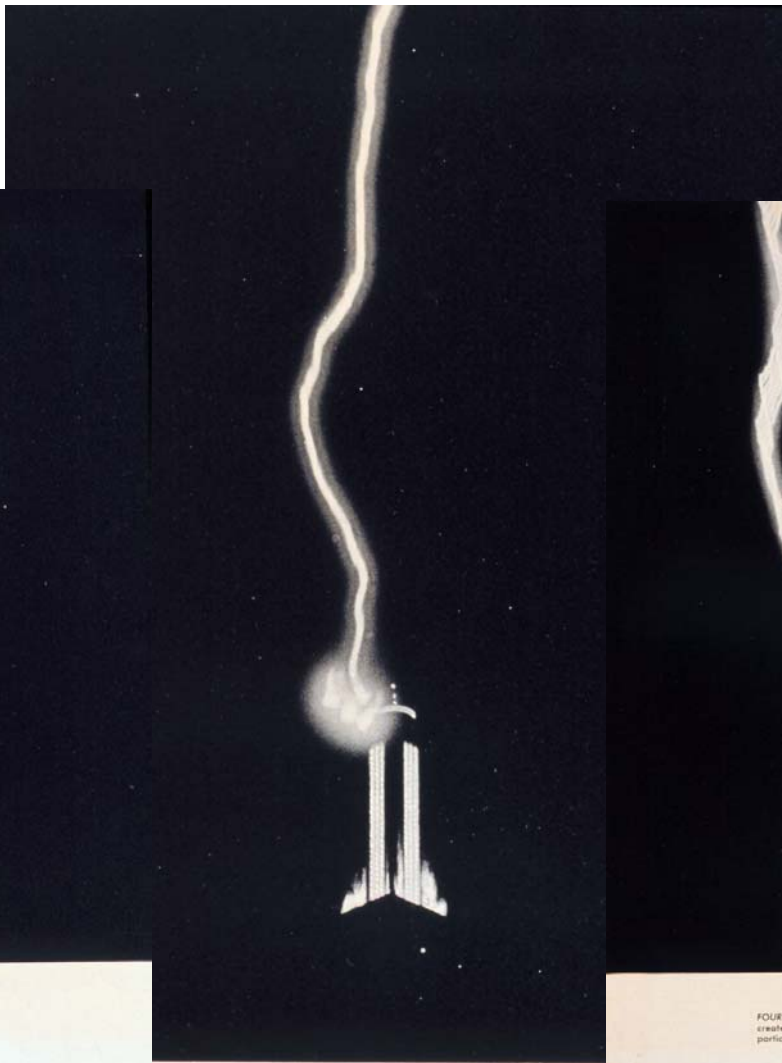
A 3D illustration of the failure of the electrogeometrical model. Junction with the structure. $I=10$ kA, $R_v=2$, $W=40$ m, $H=100$ m



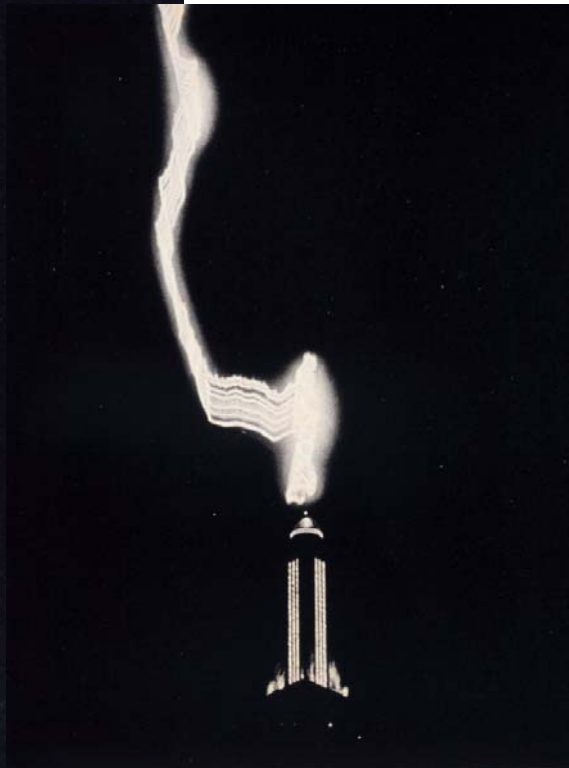
A 3D illustration of a protected structure. Junction with the Franklin rod. $I=10$ kA, $R_v=2$ $W=40$ m, $H=100$ m



THREE—Action. Quickly repeated small flashes create a ribbon of fire. Notice the reflection on the metal cap of the tower.



FIVE—A Miss. This powerful single stroke missed the lightning rods and struck the side of the tower some 60 feet lower down. The flame bursting out towards the left is at least 40 feet long.



FOUR—Power. Heavier discharges at intervals of $\frac{1}{3}$ to $\frac{1}{2}$ second create a pillar of flame as luminous as the sun. The horizontal portion shows the upward drift of the path of discharge.

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HELITA

 CNRS

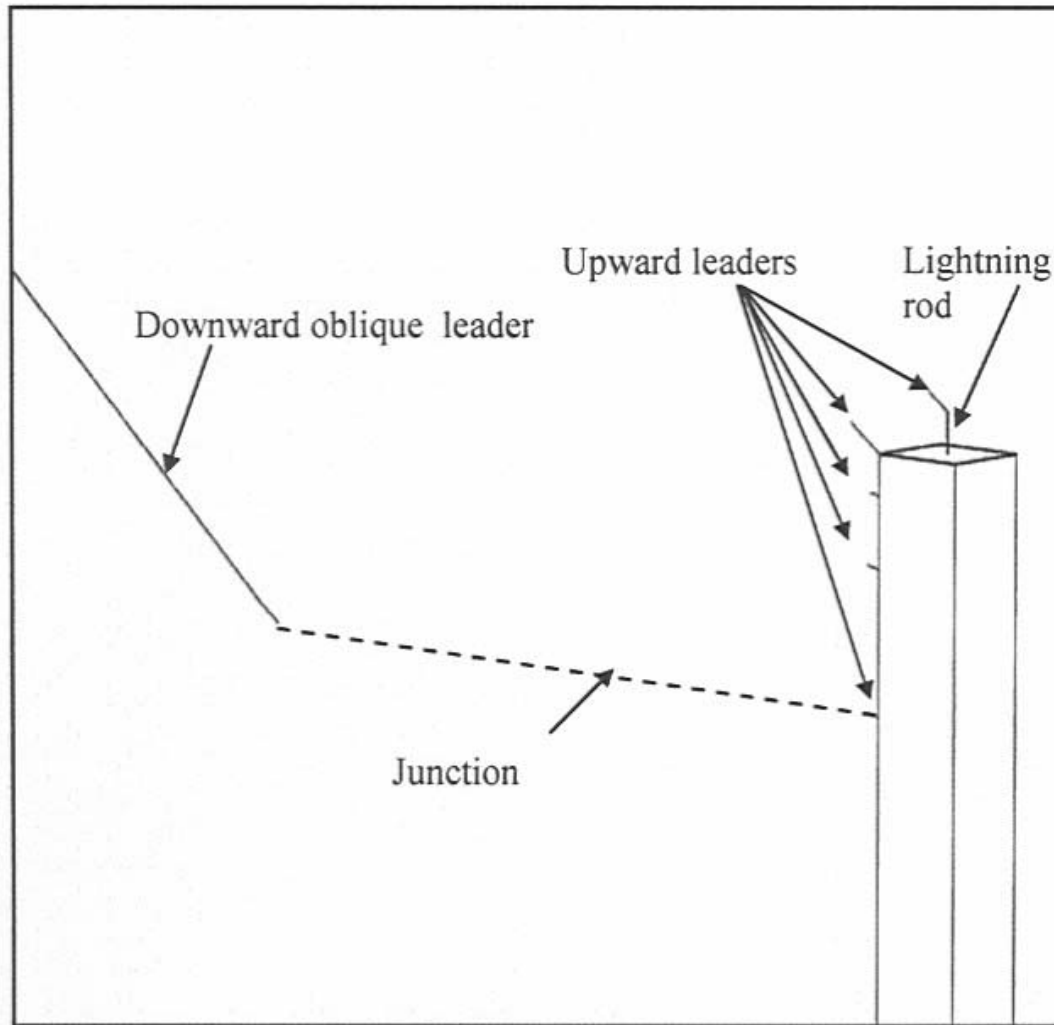
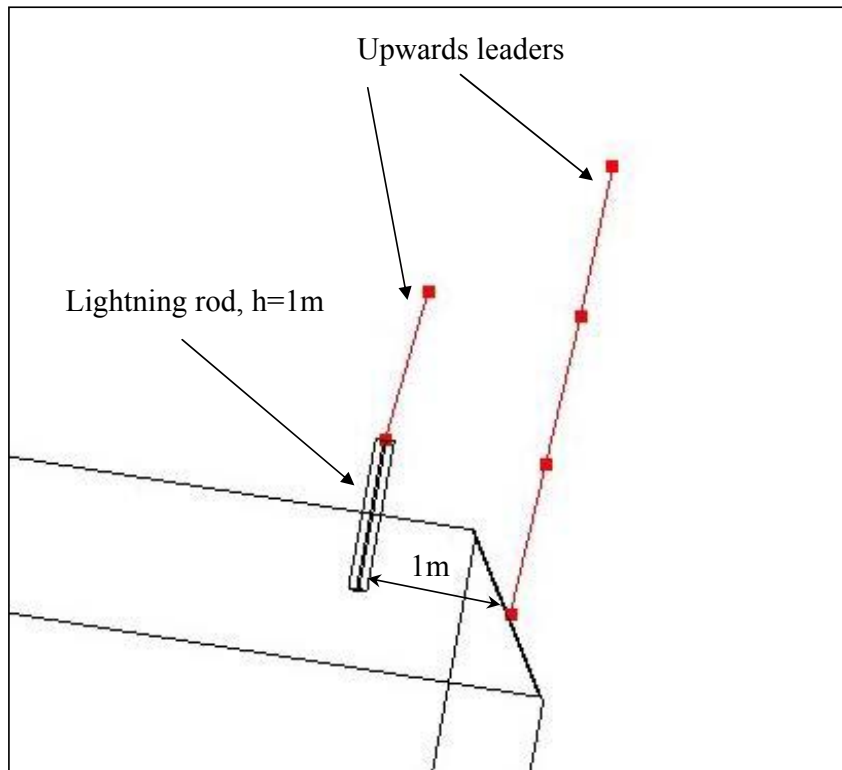
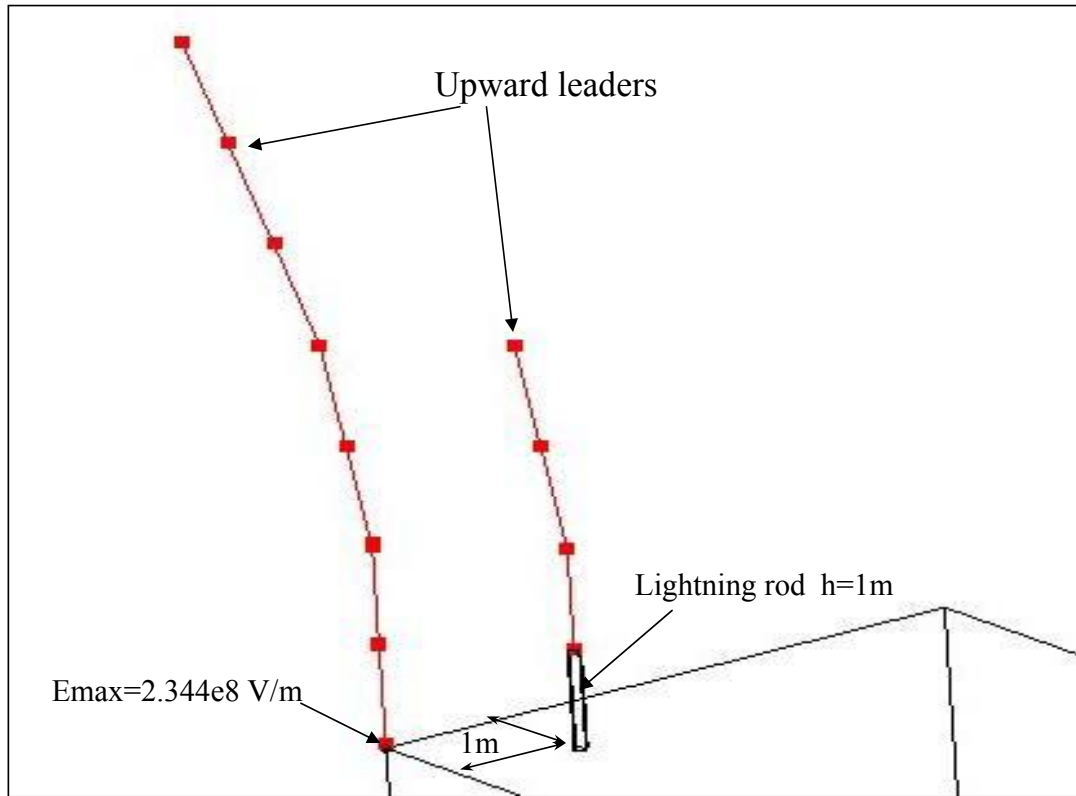


Fig. 10. A 3D illustration of a protected structure strike by oblique downward leadered structure. $I=50 \text{ kA}$, $R_v=1$, $h=11 \text{ m}$.



**An example of a competition between 2 upward leaders.
Junction with the edges. $I=10\text{ kA}$, $R_v=2$**



**An example of a competition between 2 upward leaders.
Junction with the corner. $I=10 \text{ kA}$, $R_v=2$**

CONCLUSIONS

On elevated buildings :

- Lightning strikes preferentially corners and edges**
- Electric field is lower at the roof centre**
- Lightning protection bypass possible
if lightning rod is not tall enough**
- Sideflash with oblique downward leader**