CSE468
Information Conflict

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Lecture 06

Hypergames vs Information Conflict Strategies

Reference Sources and Bibliography

- There are few references dealing with hypergames in information conflict. References include:

1. **Fraser N.M, Hipel K.W., *Conflict Analysis – Models and Resolutions*, North-Holland, New York, 1984.**
2. **Kopp, Carlo, *Shannon, Hypergames And Information Warfare,* Conference Paper, Proceedings of the 3rd Australian Information Warfare & Security Conference 2002. Slides (PDF).**
3. **Kopp, Carlo, *Boyd, Metcalfe and Amdahl - Modelling Networked Warfighting Systems,*Conference Paper, Proceedings of the 5th Australian Information Warfare & Security Conference 2004. Slides (PDF).**
4. **Lachlan Brumley, *HYPANT: A Hypergame Analysis Tool*, Honours Thesis, 2003, Monash University SCSSE (Website).**

Limitations of the Shannon Model

1. The Shannon model provides a powerful tool for capturing the interactions between adversaries and the information carrying channel.
2. The Shannon model cannot capture how the manipulation of the channel might be reflected in the behaviour of the adversaries.
3. How can we best model the interaction of adversaries given their use of some combination of the four canonical strategies?

Hypergames (Bennett/Fraser/Hipel)

- Hypergames are games in which the respective adversaries may not be fully aware of the nature of the engagement they are participating in, or indeed that they are actually participating in an engagement.
- Characteristics include:

1. Players may have false perceptions of the intent or aims of the other players.
2. Players may not understand the choices available to other players.
3. Players may not know who other players in the game may be.
4. A player may be subject to one or more of the previous misperceptions of the game.

- The 'perfect information' assumption does not hold for a hypergame.

Hypergame Fundamentals (1)

- In practical terms, players in hypergames have perceptions of the engagement which may not reflect the true nature of the engagement, resulting in decisions and outcomes which may not reflect the interests or indeed intent of the players.
- In classical game theory players typically have *perfect information* about the state of the game, there are no misperceptions of previous moves.
- In the hypergame model, the players' perceptions of reality are generally not considered to map one to one on the reality of the game they are parties to.

Hypergame Fundamentals (2)

- A general description of a hypergame is given in (Fraser, 1984), in which n players each perceive a particular game:

$$H = \{G_1, G_2, G_3, \ldots. G_n\}$$

- Each game perceived by the participating players can be described with a set of outcomes, as perceived by that player:

$$G_i = \{O_1, O_2, O_3, \ldots. O_m\}$$

- We assume n and m are finite, but may be quite large for complex games.

Hypergame Fundamentals (3)

- Each outcome, in turn, comprises a set of possible actions (moves) by respective players, as perceived by player *i* :

$$O_i = \{\{A_1, A_2, \ldots A_q\}_1, \{A_1, A_2, \ldots A_p\}_2 \ldots. \{A_1, A_2, \ldots A_r\}_n\}$$

- Each player will seek to execute actions which yield a set of outcomes most favourable to that player, should we assume the player is rational.
- The most common analysis performed on hypergames is a stability analysis to establish whether an equilibrium state exists.
- It is customary to treat hypergames as ordinal games since ranking of outcomes is simpler than finding payoffs.

Hypergame Stability [Fraser/Hipel 1979]

- *Rational* – a given player cannot make a unilateral improvement (UI) from a given outcome.
- *Sequentially sanctioned* – for all UIs available to a player, the opponent can perform credible actions which result in a less preferred outcome than the current one.
- *Unstable* – a player has at least one UI from which the opponent cannot take any credible measure which results in a less preferred outcome.
- *Simultaneously sanctioned* – if both players simultaneously change their strategies from an unstable outcome, an outcome less preferred by either or both players may arise. This deters both players.

Hypergame Example [Fraser/Hipel] (1)

Table 1.1 Players, Options, and Outcomes for the Cuban Missile Crisis

Option	Outcomes											
U.S.												
Air strike	0	1	0	1	0	1	0	1	0	1	0	1
Blockade	0	0	1	1	0	0	1	1	0	0	1	1
USSR												
Withdraw	0	0	0	0	1	1	1	1	0	0	0	0
Escalate	0	0	0	0	0	0	0	0	1	1	1	1
Decimal	0	1	2	3	4	5	6	7	8	9	10	11

Hypergame Example [Fraser/Hipel] (2)

Table 1.2 Preference Vector for the United States in the Cuban Missile Crisis

U.S.												
Air strike	0	0	1	1	0	1	1	0	1	1	0	0
Blockade	0	1	0	1	1	0	1	0	1	0	1	0
USSR												
Withdraw	1	1	1	1	0	0	0	0	0	0	0	0
Escalate	0	0	0	0	0	0	0	0	1	1	1	1
Decimal	4	6	5	7	2	1	3	0	11	9	10	8

Table 1.3 Preference Vector for the USSR in the Cuban Missile Crisis

U.S.												
Air strike	0	0	0	0	1	1	1	1	1	1	0	0
Blockade	0	0	1	1	0	0	1	1	1	0	1	0
USSR												
Withdraw	0	1	1	0	1	0	1	0	0	0	0	0
Escalate	0	0	0	0	0	0	0	0	1	1	1	1
Decimal	0	4	6	2	5	1	7	3	11	9	10	8

Hypergame Example [Fraser/Hipel] (3)

Table 1.4 Stability Analysis Tableau for the Cuban Missile Crisis[a]

												U.S.
E	*E*	×	×	×	×	×	×	×	×	×	×	overall stability
r	*s*	*u*	*u*	*r*	*u*	*u*	*u*	*r*	*u*	*u*	*u*	player stability
4	6	5	7	2	1	3	0	11	9	10	8	preference vector
	4	4	4		2	2	2		11	11	11	UIs
		6	6			1	1			9	9	
			5				3				10	
												USSR
r	*s*	*r*	*u*	*r*	*u*	*r*	*u*	*u*	*u*	*u*	*u*	player stability
0	4	6	2	5	1	7	3	11	9	10	8	preference vectors
	0		6		5		7	7	5	6	0	UIs
								3	1	2	4	

[a]Simultaneous stability calculations:

$2 + 5 - 1 = 6$, preferred by both players over 1;
$2 + 7 - 3 = 6$, preferred by both players over 3;
$11 + 0 - 8 = 3$, preferred by both players over 8;
$11 + 5 - 9 = 7$, preferred by both players over 9;
$11 + 6 - 10 = 7$, preferred by both players over 10.

Outcomes 1, 3, and 8–10 remain unstable for both players.

Hypergame Example [Fraser/Hipel] (4)

Table 3.1 Preference Vector for the United States as Perceived by the USSR in the Cuban Missile Crisis Hypergame

U.S.												
Air strike	0	0	0	0	1	1	1	1	1	1	0	0
Blockade	0	0	1	1	0	0	1	1	1	0	1	0
USSR												
Withdraw	1	0	1	0	1	0	1	0	0	0	0	0
Escalate	0	0	0	0	0	0	0	0	1	1	1	1
Decimal	4	0	6	2	5	1	7	3	11	9	10	8

Table 3.2 Preference Vectors in a Hypergame

Player perceived	Game perceived by player			
	1	2	⋯	n
1	V_{11}	V_{12}	⋯	V_{1n}
2	V_{21}	V_{22}	⋯	V_{2n}
⋮	⋮	⋮	⋯	⋮
n	V_{n1}	V_{n2}	⋯	V_{nn}
	G_1	G_2	⋯	G_n

Hypergame Example [Fraser/Hipel] (5)

Table 3.3 Preference Vectors in the Cuban Missile Crisis Hypergame

Player perceived	U.S. perception	Soviet perception
U.S.	4 6 5 7 2 1 3 0 11 9 10 8	4 0 6 2 5 1 7 3 11 9 10 8
USSR	0 4 6 2 5 1 7 3 11 9 10 8	0 4 6 2 5 1 7 3 11 9 10 8

Hypergame Example [Fraser/Hipel] (6)

Table 3.4 Stability Analysis Tableau of the First Level Hypergame for the Cuban Missile Crisis[a]

American game (G_a)

×	*E*	×	×	×	×	×	×	×	×	×	×	overall
E	*E*	×	×	×	×	×	×	×	×	×	×	U.S.
r	*s*	*u*	*u*	*r*	*u*	*u*	*u*	*r*	*u*	*u*	*u*	
4	6	5	7	2	1	3	0	11	9	10	8	
	4	4	4		2	2	2		11	11	11	
		6	6			1	1			9	9	
			5				3				10	
												USSR
r	*s*	*r*	*u*	*r*	*u*	*r*	*u*	*u*	*u*	*u*	*u*	
0	4	6	2	5	1	7	3	11	9	10	8	
	0		6		5		7	7	5	6	0	
								3	1	2	4	

Soviet game (G_s)

												U.S.
r	*r*	*u*	*u*	*u*	*u*	*u*	*u*	*r*	*u*	*u*	*u*	
4	0	6	2	5	1	7	3	11	9	10	8	
		4	0	4	0	4	0		11	11	11	
				6	2	6	2			9	9	
						5	1				10	
												USSR
E	×	×	×	×	×	×	×	×	×	×	×	
r	*u*	*r*	*u*	*r*	*u*	*r*	*u*	*u*	*u*	*u*	*u*	
0	4	6	2	5	1	7	3	11	9	10	8	
	0		6		5		7	7	5	6	0	
								3	1	2	4	

[a]United States is unaware of hypergame.

Hypergame Example [Fraser/Hipel] (7)

Table 3.5 Second Level Hypergame in Matrix Form

Player perceived	Hypergame perceived by player 1	2	$\cdots$	n
1	G_{11}	G_{12}	$\cdots$	G_{1n}
2	G_{21}	G_{22}	$\cdots$	G_{2n}
$\vdots$	$\vdots$	$\vdots$	$\cdots$	$\vdots$
n	G_{n1}	G_{n2}	$\cdots$	G_{nn}
	$\overline{H_1}$	$\overline{H_2}$	$\cdots$	$\overline{H_n}$

Hypergame Example [Fraser/Hipel] (8)

Table 3.6 Cuban Missile Crisis as a Second Level Hypergame

	Cuban missile crisis second level hypergame H^2	
	American hypergame H_a	
	American game G_{aa}	*Soviet game* G_{sa}
U.S.	4 6 5 7 2 1 3 0 11 9 10 8	4 0 6 2 5 1 7 3 11 9 10 8
USSR	0 4 6 2 5 1 7 3 11 9 10 8	0 4 6 2 5 1 7 3 11 9 10 8
	Soviet hypergame H_s	
	American game G_{as}	*Soviet game* G_{ss}
U.S.	4 0 6 2 5 1 7 3 11 9 10 8	4 0 6 2 5 1 7 3 11 9 10 8
USSR	0 4 6 2 5 1 7 3 11 9 10 8	0 4 6 2 5 1 7 3 11 9 10 8

Hypergame Example [Fraser/Hipel] (9)

Table 3.7 Stability Analysis Tableau of the Second Level Hypergame for the Cuban Missile Crisis[a]

U.S.											
×	*E*	×	×	×	×	×	×	×	×	×	×
×	*E*	×	×	×	×	×	×	×	×	×	×
r	*s*	*u*	*u*	*r*	*u*	*u*	*u*	*r*	*u*	*u*	*u*
4	6	5	7	2	1	3	0	11	9	10	8
	4	4	4		2	2	2		11	11	11
		6	6			1	1			9	9
			5				3				10
U.S. perceived by USSR											
r	*r*	*u*	*u*	*u*	*u*	*u*	*u*	*r*	*u*	*u*	*u*
4	0	6	2	5	1	7	3	11	9	10	8
		4	0	4	0	4	0		11	11	11
				6	2	6	2			9	9
						5	1				10
USSR											
E	×	×	×	×	×	×	×	×	×	×	×
r	*u*	*r*	*u*	*r*	*u*	*r*	*u*	*u*	*u*	*u*	*u*
0	4	6	2	5	1	7	3	11	9	10	8
	0		6		5		7	7	5	6	0
								3	1	2	4

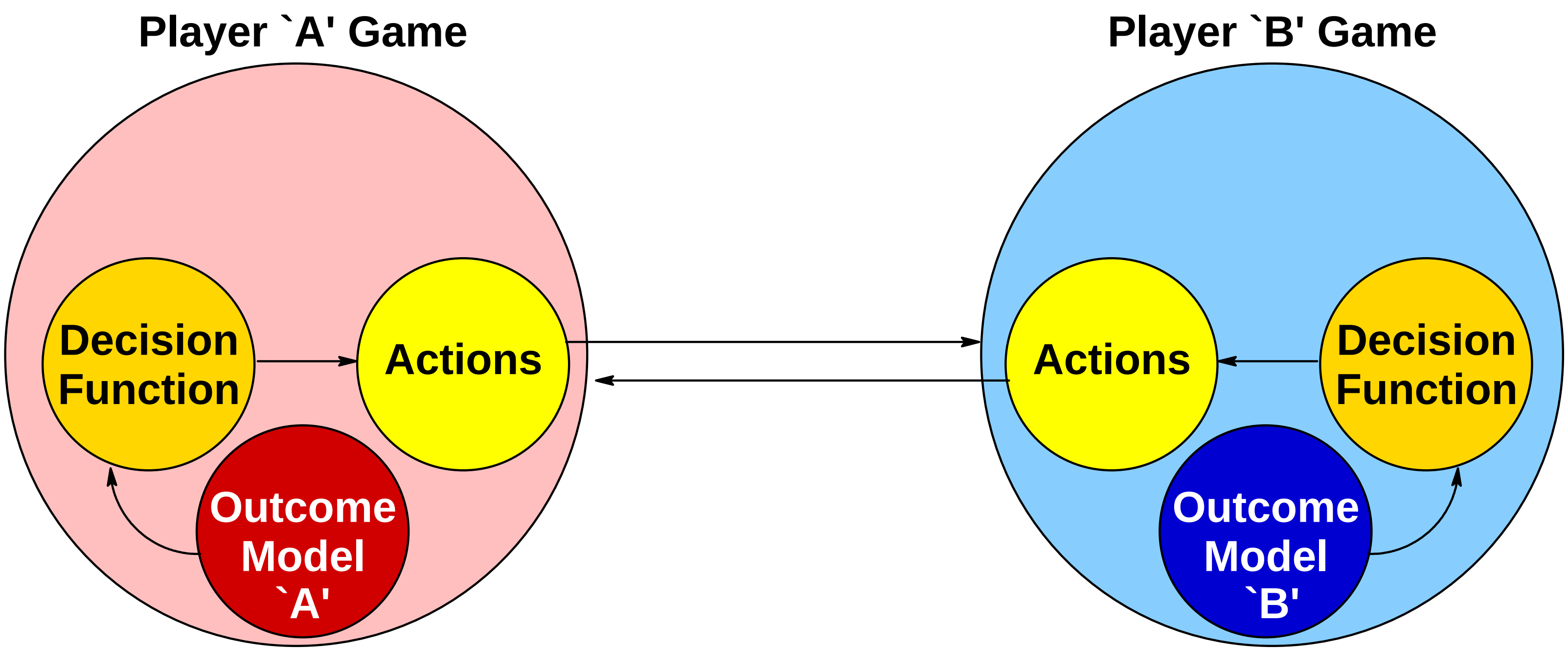
[a]United States is aware of hypergame.

Boyd vs Hypergames

1. Boyd (1986) defines the ‘OODA Loop’ as a model for an engagement.
2. A player’s perception of a game is described by the ‘Observation-Orientation’ phase of an OODA Loop.
3. A player’s choices in a game are described by the ‘Decision-Action’ phase of an OODA Loop.
4. Boyd’s OODA loop describes the basic dynamic in a Game/Hypergame.

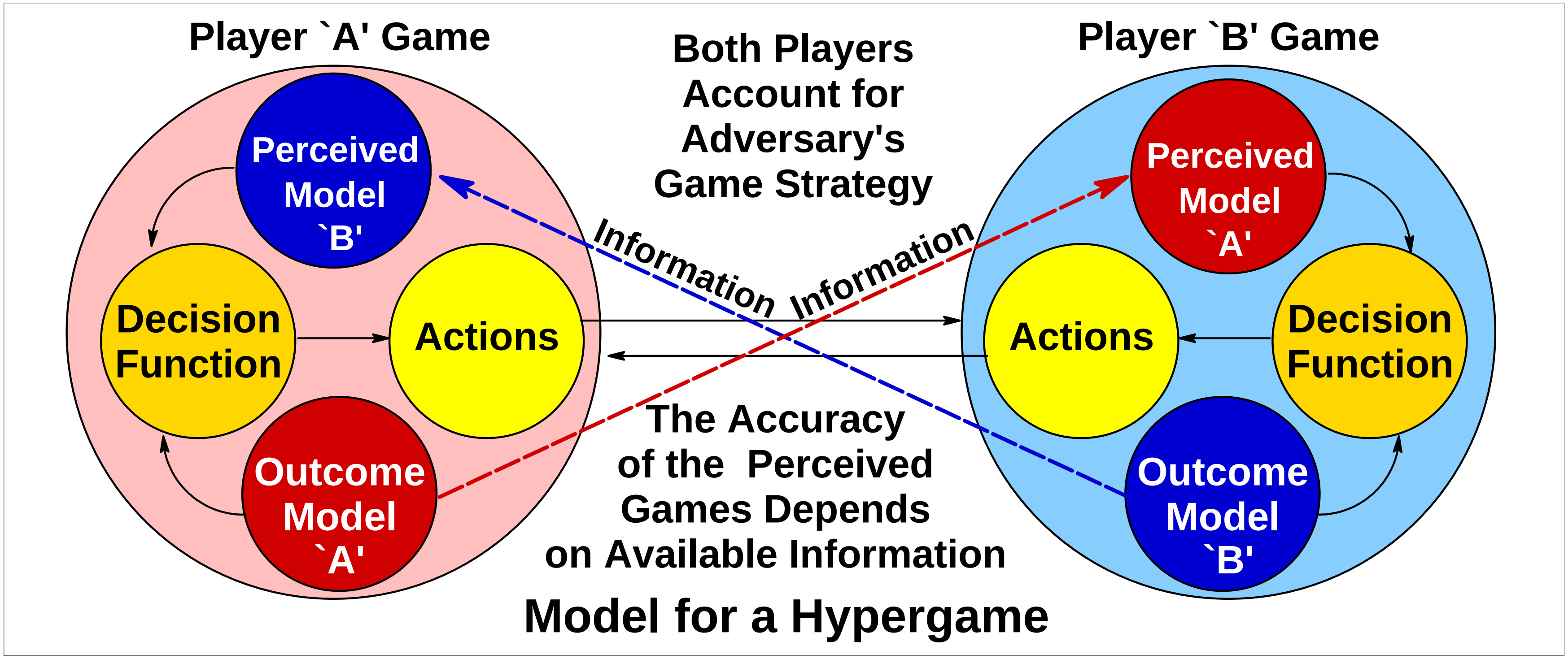
- Information Warfare is a means to an end in a hypergame - it permits alteration of an opponent’s perception of the game in a manner yielding an advantage to the player using it.

A Simple Game vs the OODA Loop



Model for a Game

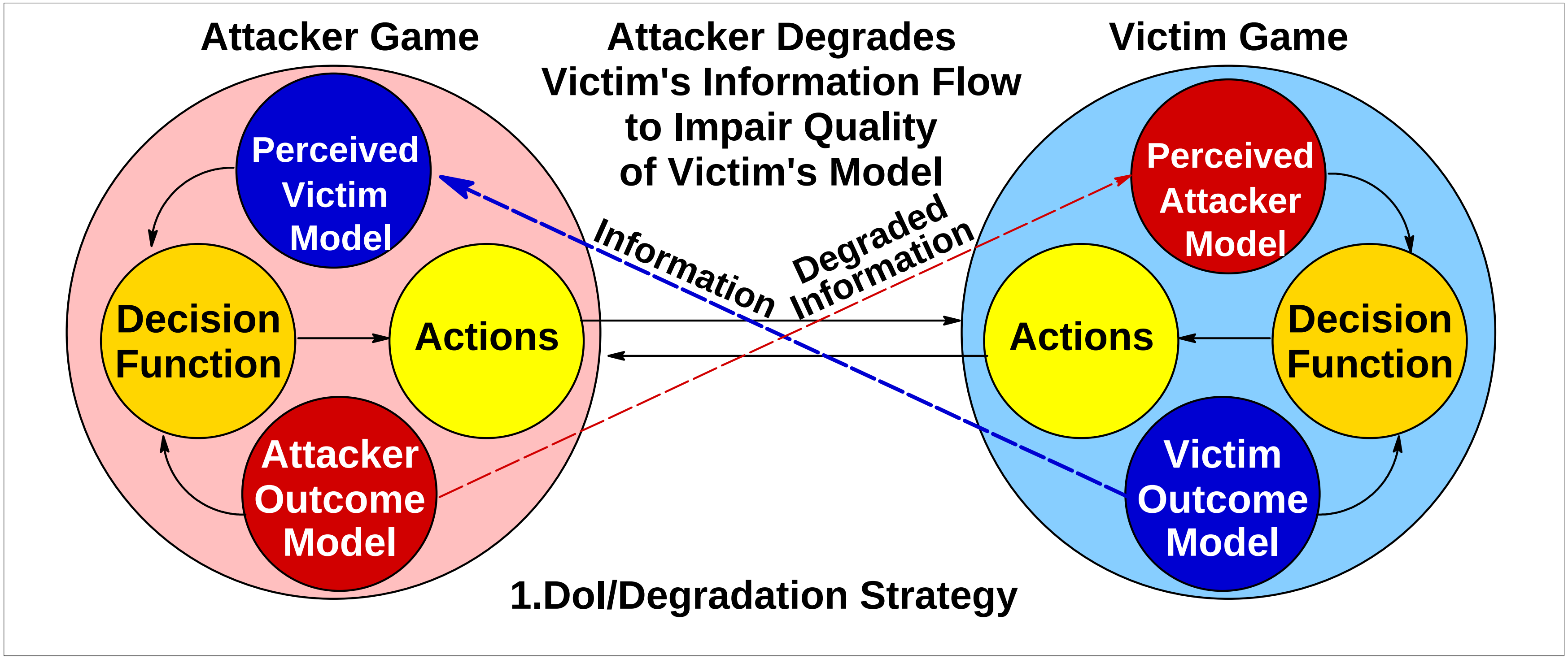
A Hypergame vs the OODA Loop



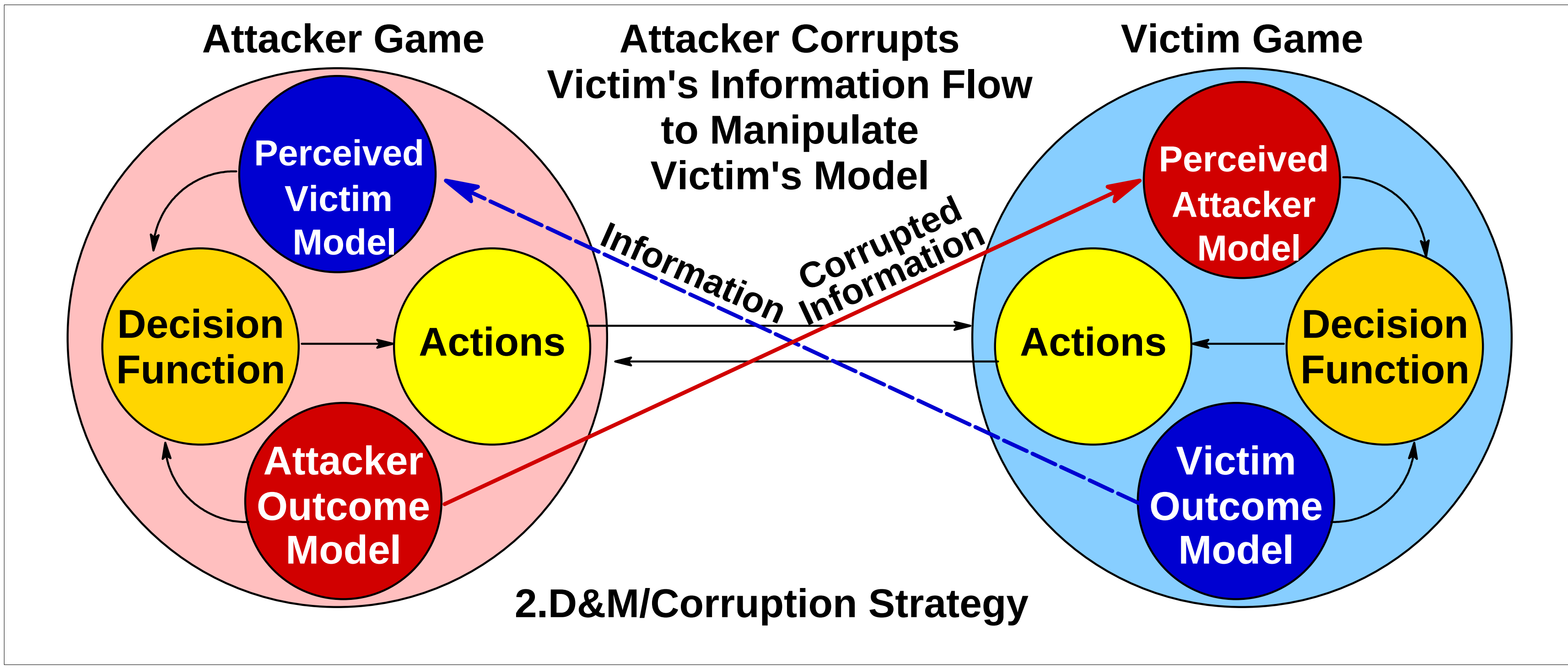
The Hypergame Model vs Canonical Strategies

1. **Degradation** - this strategy is central to hypergames in which either the presence of a player, or the intent of a player is to be concealed from another.
2. **Corruption** - is applied in a hypergame in order to alter another player's perception of the game at hand. It amounts to directly changing another player's perception of the game.
3. **Denial (via Destruction)** - is applied by a player in a hypergame to prevent another player from perceiving the state of the game. Denial via destruction can betray the player using it.
4. **Denial (via Subversion)** - is a strategy where a unilateral action by a player alters the perception of the situation by a victim player to elicit a self destructive unilateral action.

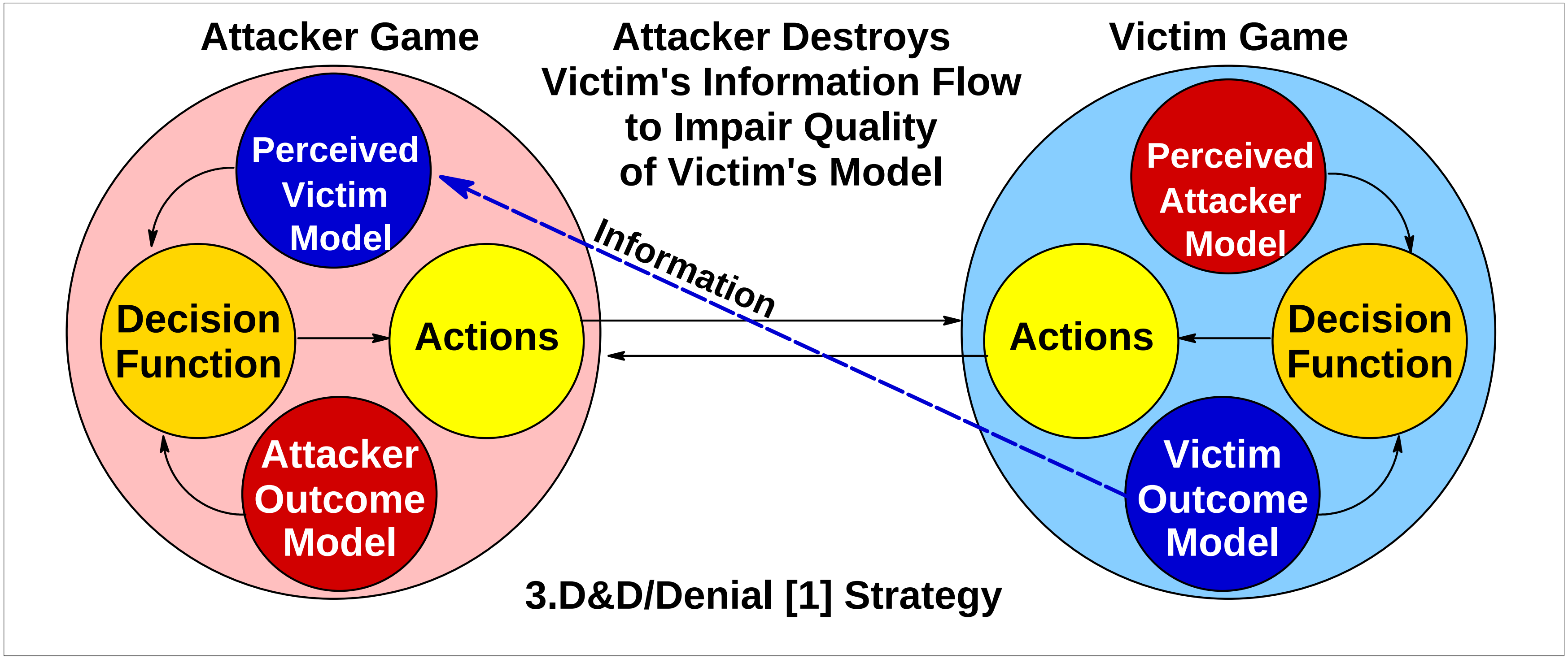
Hypergame using Degradation



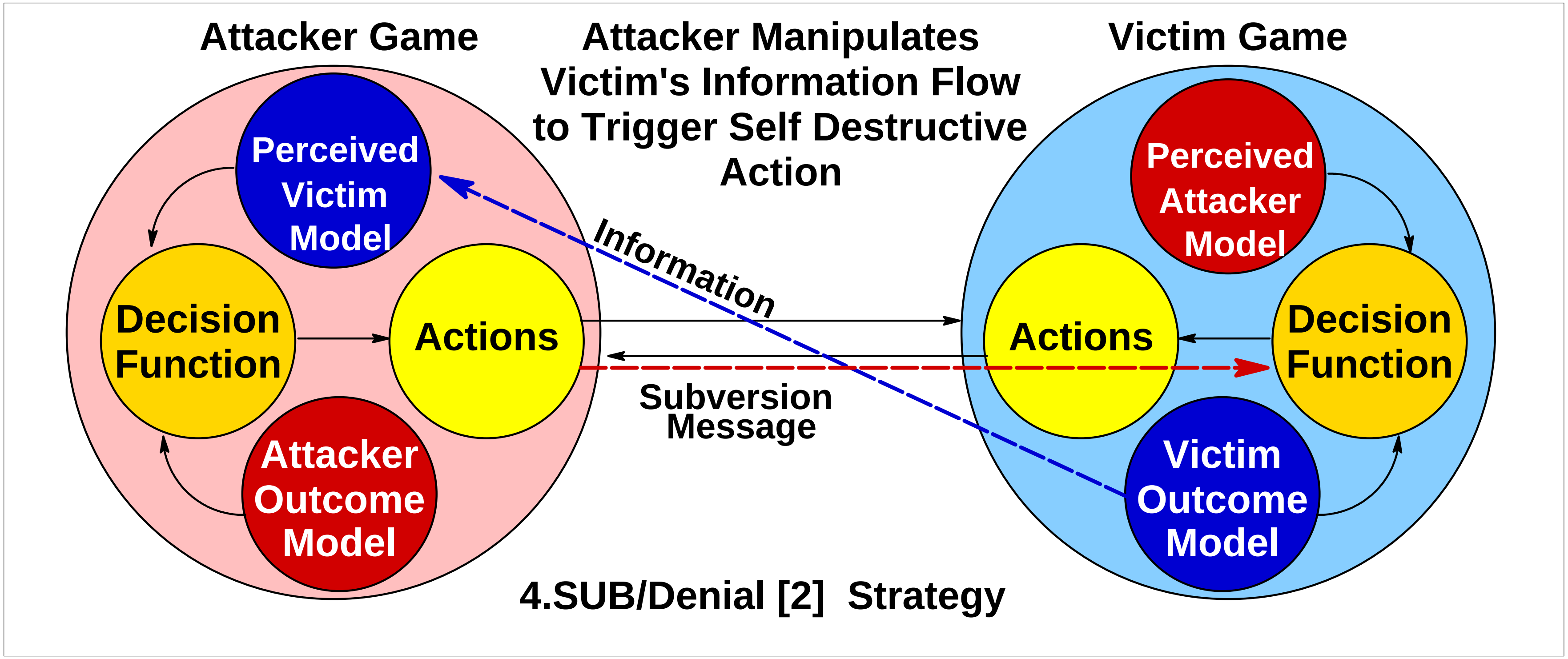
Hypergame using Corruption



Hypergame using Denial (via Destruction)



Hypergame using Denial (via Subversion)



Considerations

- All second and third order hypergames model misperceptions by players. Misperceptions may arise due to limitations in players' capabilities, or may arise due to the application of information conflict techniques.
- Players in such games have to confront not only the complexity of the hypergame, and understanding its options and outcomes, but also must understand the sensitivity of the game to a deception.
- Literature on hypergames focusses largely on finding outcomes which are stable ie equilibria.
- In real scenarios players will often think in terms of iterated hypergames, each with unstable outcomes intended to provide an advantage in a subsequent iteration.

Considerations (2)

- If we aim to analyse and understand the aims of a deception, knowledge of the aims of the players gain be gained by modelling the conflict as a second order hypergame.
- In general, players opting to apply a compound strategy in a deception will be playing a second level hypergame with the aim of the deception being to alter opponents' perceptions to their advantage.
- Third and higher level hypergames can present difficulty in modelling as the problem can acquire recursive properties, ie 'my perception of his perception of my perception of his perception ….'
- In practice second level hypergames are most useful.

Key Points

- Hypergames are metagames which account for imperfect information in a game.
- Hypergames provide a good model for representing interactions between adversaries executing actions in information conflict engagements.
- Hypergames provide a good model for representing the dynamic of Boyd's OODA loop.

Tutorial

- Q&A
- Work through examples in detail