

Phase 3 | Relational Model | Prison Management System | BruteForce

Changes in the ER diagram:

1. Visitors is a weak entity type of the strong entity type Prisoner as mentioned in our SRS document, already related by the identifying relationship 'Visiting'. The Prisoner ID + Visitor name serves as the primary key for the Visitor entities.
Hence, there is no need to add the attribute Prisoner Name to Entity type Visitor as that is an implementation detail and not an ER model requirement.
2. Emergency Contacts is a weak entity type of the strong entity type Prisoner as mentioned in our SRS document, already related by an identifying relationship. The Prisoner ID + Emergency Contact name serves as the primary key for the Emergency Contact entities.
Hence, there is no need to add the attribute Prisoner Name to Entity type Emergency Contact as that is an implementation detail and not an ER model requirement.
3. Cardinality constraints for any of the relationships have not been depicted despite them being clearly mentioned in the SRS document.
4. Attributes of the Guards subclass, namely Wing and Shift, have not been shown in the ER diagram.
5. The one-to-many relationship between Prison Officers (Prison Staff entity type) and Guards (Prison Staff entity type) has not been drawn despite it being mentioned in the SRS document.
6. The first flaw pointed out, that is the lack of First Name, Middle Name and Last Name in the Prisoner entity type is baseless as the SRS document clearly states that the Name attribute of the Prisoner Entity Type is a composite attribute entailing these three attributes.

Mapping the ER Model to a Relational Schema

Step 1: Mapping of Regular Entity Types:

1. A relation PRISONERS is created with the following attributes:
 - a. Prisoner ID
 - b. First Name

- c. Middle Name
- d. Last Name
- e. Sex
- f. Date of Birth
- g. Weight
- h. Height
- i. Blood group
- j. Medical history
- k. Arrival date
- l. Sentence
- m. Cell
- n. Security level

The Prisoner ID forms the primary key of this relation.

2. A relation OFFENCES is created with the following attributes:

- a. Offence ID
- b. Description
- c. Date-Time
- d. Location
- e. Severity

The Offence ID serves as the primary key for this relation.

3. A relation JOBS is created with the following attributes:

- a. Job ID
- b. Job Name
- c. Working hours

The Job ID serves as the primary key of this relation.

4. A relation PRISON STAFF is created with the following attributes.

- a. Staff ID
- b. First Name
- c. Middle Name
- d. Last Name
- e. Date of Birth
- f. Sex
- g. Address

- h. Phone
- i. Post
- j. Salary

The Staff ID serves as the primary key of this relation.

5. A relation APPEALS is created with the following attributes:

- a. Appeal ID
- b. Filing Date
- c. Hearing Date
- d. Status

The Appeal ID serves as the primary key of this relation.

Step 2: Mapping of weak entity types

1. A relation VISITORS is created with the following attributes:

- e. Prisoner ID
- f. First Name
- g. Middle Name
- h. Last Name
- i. Relationship
- j. Address
- k. Phone

The Prisoner ID is a foreign key which references the ID of the Prisoner entity that owns the corresponding Visitor entity. The Prisoner ID (foreign key) and the First Name, Middle Name, and Last Name together constitute the primary key of this relation.

2. Create a relation EMERGENCY CONTACTS with the following attributes:

- a. Prisoner ID
- b. First Name
- c. Middle Name
- d. Last Name
- e. Relationship
- f. Address
- g. Phone

The Prisoner ID is a foreign key which references the ID of the Prisoner entity that owns the corresponding Emergency Contact entity. The Prisoner ID (foreign key) and the First Name, Middle Name, and Last Name together constitute the primary key of this relation.

Step 3: Mapping of binary 1:1 relationship types

1. Cellmates

This relationship type is stored as an attribute in the Prisoner relation. This is achieved by adding an attribute Cellmate ID which is a foreign key, referencing the Prisoner ID of the related Prisoner entity. This attribute can take NULL values if the Prisoner entity does not have a cellmate.

Step 4: Mapping of binary 1:N relationship types

1. Between Prisoners and Appeals

The Appeals entity type lies on the N-side of the relationship. Hence, this relationship can be mapped by adding to the Appeals relation an attribute Prisoner ID. This attribute is a foreign key referencing the Prisoner ID of the Prisoner entity to which that Appeal entity is related. This attribute cannot be NULL, because each Appeal entity must be related to exactly one Prisoner entity. A reverse-lookup on the Prisoner ID will yield the zero or more Appeal entities associated with any given Prisoner entity.

2. Between Prison Officers and Guards

(Guards are a subclass of Prison Staff. See section 8 for details)

The Guards entity type lies on the N-side of the relationship. Hence, this relationship can be mapped by adding to the Guards relation an attribute Supervisor ID. This attribute is a foreign key that references the Staff ID of the Prison Staff entity which is the supervisor of the corresponding Guard entity. This attribute cannot be NULL because each Guard entity must have exactly one supervising Prison Staff entity. A reverse-lookup on the Staff ID will yield the zero or more Guard entities being supervised by any given Prison Staff entity. A functional requirement demands that only Prison Staff entities with Post set as Prison Officer be involved in this relationship on the 1-side.

Step 5: Mapping of binary M:N relationship types

1. Between Guards and Prisoners

This is a partial M:N relationship, which is modelled using a separate cross-reference relation, OVERSEE, which stores the following attributes:

- a. Guard ID, which is a foreign key referencing the Staff ID of the corresponding Guard entity
- b. Prisoner ID, which is a foreign key referencing the Prisoner ID of the corresponding Prisoner entity
- c. Wing, in which the Prisoner resides and which the Guard patrols

The Guard ID and Prisoner ID together form the primary key of this relation.

Step 6: Mapping of multivalued attributes

1. Crime attribute of the Prisoner entity type

A separate relation, CRIMES is created with the following attributes:

- a. Prisoner ID, a foreign key referencing the Prisoner ID of the Prisoner entity
- b. Crime

These two attributes together serve as the primary key of this relation.

2. Type attribute of the Offence entity type

A separate relation, OFFENCE TYPES, is created with the following attributes:

- a. Offence ID, a foreign key referencing the Offence ID of the Offence entity
- b. Type

These two attributes together serve as the primary key of this relation.

Step 7: Mapping of ternary and quaternary relationship types

1. Incidents

This is a ternary relationship such that every Offence entity is related to one or more Prisoner entities and zero or more Guard entities. Hence, this

relationship is modeled as two cross reference tables, with the following attributes:

a. INCIDENT PRISONERS

- i. Offence ID, which is a foreign key referencing the Offence ID of the related Offence entity
- ii. Prisoner ID, which is a foreign key referencing the Prisoner ID of the Prisoner entity involved

The Offence ID and Prisoner ID together serve as the primary key of this relation.

b. INCIDENT GUARDS

- i. Offence ID, which is a foreign key referencing the Offence ID of the related Offence entity
- ii. Guard ID, which is a foreign key referencing the Staff ID of the Guard entity present at the scene

This relationship cannot be modeled as a single cross reference table with the Offence ID, Prisoner ID and Guard ID as foreign and primary keys, because there could be no guards associated with the incident, however primary keys can't be null. In the current schema, an equi-join on the Offence ID between these two tables will link the appropriate Guard, Prisoner and Offence entities.

2. Visits

This is a ternary relationship in which every *visit* corresponds to exactly one Visitor entity, one Prisoner entity and one Guard entity. All three of them can be associated with multiple visits. Hence, this relationship is modeled as a cross-reference relation christened VISITS, with the following attributes:

- a. Prisoner ID, which is a foreign key referencing the Prisoner ID of the Prisoner entity being visited
- b. Visitor First Name
- c. Visitor Middle Name
- d. Visitor Last Name
- e. Guard ID, which is a foreign key, referencing the Staff ID of the Guard on watch during the visit
- f. Date-Time

The Visitor first name, middle name and last name (foreign keys) along with the Prisoner ID reference and uniquely identify the visitor associated with the visit (A prisoner can only be visited by her own Visitors). The Prisoner ID and

Date-Time together form the primary key for this relation, because a prisoner can only be involved in one visit at a particular instant in time.

3. Work Assignment

This is a quaternary relationship in which every job is associated with one or more Prisoner entities, zero or more Guard entities and at most one supervising officer (a Prison Staff entity not a member of the Guard subclass). This can be modeled by introducing the following:

- a. An attribute, Supervisor ID, in the Jobs relation, which is a foreign key referencing the Staff ID of the Prison Staff entity supervising the Job entity. This can take null values and a functional requirement demands that it only references Prison Staff entities with Post not set as Guard.
- b. A cross-reference relation, ASSIGNMENT PRISONER, with the following attributes:
 - i. Job ID, a foreign key referencing the Job ID of the corresponding Job entity
 - ii. Prisoner ID, a foreign key referencing the Prisoner ID of the Prisoner entity employed

Both these attributes together form the primary key of this relation.

- c. A cross-reference relation, ASSIGNMENT GUARD, with the following attributes:
 - i. Job ID, a foreign key referencing the Job ID of the corresponding Job entity
 - ii. Guard ID, a foreign key referencing the Guard ID of the Guard entity assigned to be on watch

This relationship cannot be modeled as a single cross-reference relation with the Job ID, Prisoner ID, Supervisor ID and Guard ID as foreign and primary key because the latter two must be able to take null values. In the current schema, an equi-join on the Job ID will relate the corresponding Job, Guard, Supervisor and Prisoner entities.

Step 8: Mapping specializations

1. The Guard subclass of Prison Staff

This specialization is stored as a separate relation, which augments the

Prison Staff relation by storing the additional attributes required by the Guards subclass. All tuples in this relation, christened GUARDS, must correspond to already existing tuples in the Prison Staff relation, and a functional requirement demands that all such tuples must have their Post attribute set to Guard.

The Guard relation has the following attributes:

- a. Staff ID, a foreign key referencing the Staff ID of the corresponding Prisoner Staff entity
- b. Shift

The Staff ID serves as the primary key of this relation.

Conversion to Normal Forms

Step 1: Conversion to First Normal Form

The relational schema described above is already in the first normal form, as it neither contains composite or multivalued attributes, nor nested relations. All composite attributes have already been broken into separate attributes that take atomic values and all multivalued attributes have been decomposed into separate relations in section 6.

Step 2: Conversion to Second Normal Form

The second normal form demands that every non-prime attribute be fully functionally dependent on the primary key.

This is violated in the relation Oversee, which entails the following attributes:

- a. Guard ID, which is a foreign key referencing the Staff ID of the corresponding Guard entity
- b. Prisoner ID, which is a foreign key referencing the Prisoner ID of the corresponding Prisoner entity
- c. Wing, in which the Prisoner resides and which the Guard patrols

(The Guard ID and Prisoner ID together form the primary key.)

The Wing can be derived from either Guard ID or Prisoner ID alone. This is because the Guard ID identifies a unique Guard entity assigned to a particular wing, and similarly for the Prisoner ID. Hence, the Wing attribute is not *fully*

functionally dependent on the primary key.

To fix this, the Wing attribute is added to both the Prisoner relation and the Guard relation separately, and the entire Oversee relation is deleted. An equi-join on the Wing attribute of the Prisoner and Guard relations will yield pairs of related Prisoner and Guard entities. (The SRS document states that Guard entities assigned a particular Wing and the Prisoner entities residing in that Wing are related.)

Step 3: Conversion to Third Normal Form

The third normal form dictates that no non-prime attribute be transitively dependent on the primary key, via a non-key attribute or set of attributes.

Consider the relation Prisoners with the following attributes:

- a. Prisoner ID
- b. First Name
- c. Middle Name
- d. Last Name
- e. Sex
- f. Date of Birth
- g. Weight
- h. Height
- i. Blood group
- j. Medical history
- k. Arrival date
- l. Sentence
- m. Cell
- n. Wing
- o. Cellmate, a foreign key referencing the Prisoner ID of the corresponding Prisoner entity
- p. Security level

(Prisoner ID is the primary key of this relation.)

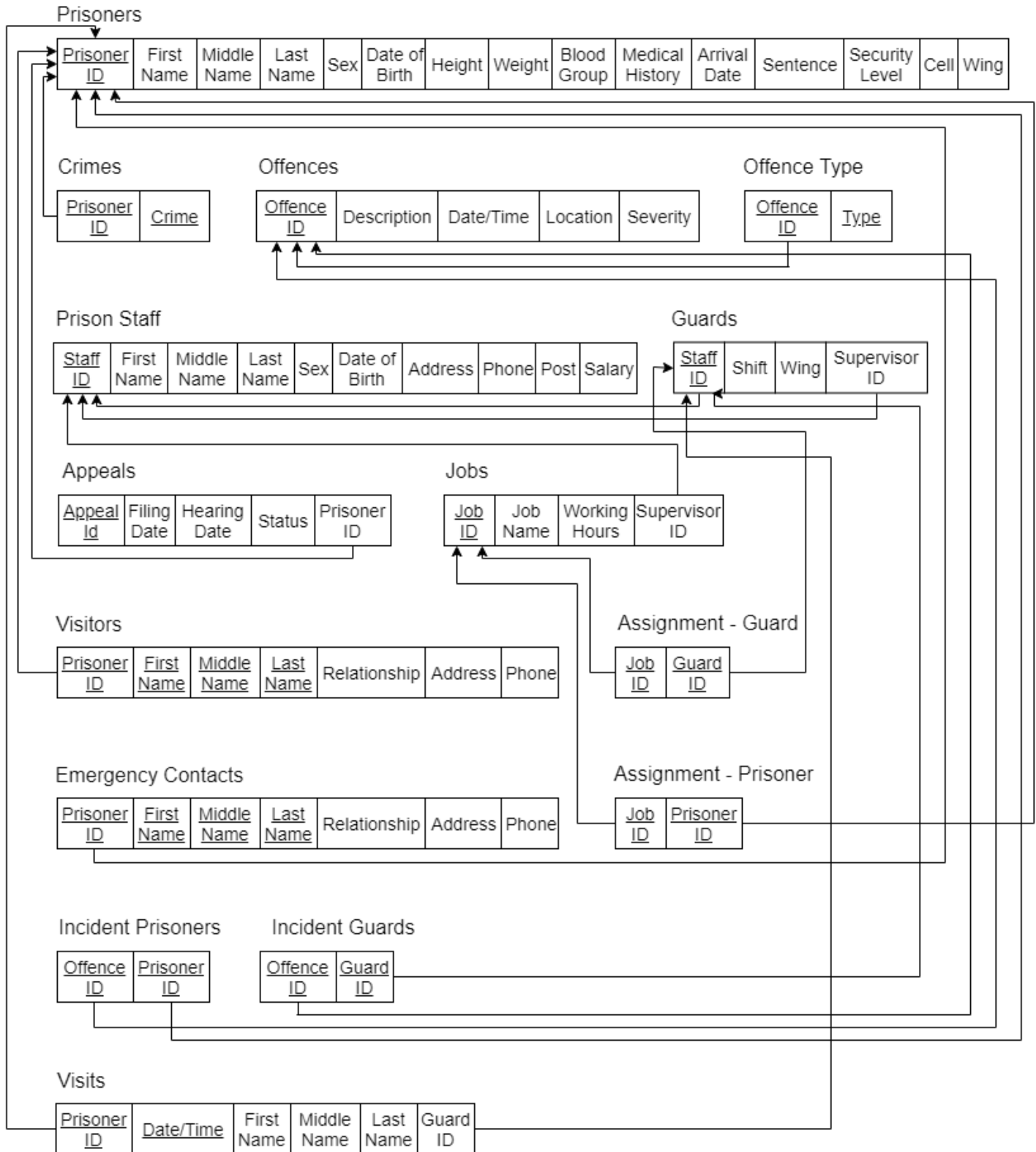
Here, the Cellmate attribute is not a candidate key, because it can take null values. However, there is a transitive dependency of the Wing and Cell attributes on the primary key via the Cellmate attribute, as the primary key determines the Cellmate, which in turn can determine the Wing and Cell attributes of the Prisoner

entity, as the corresponding cell mate Prisoner entity will have the same values for them.

To fix this, we remove the Cellmate attribute from the Prisoners relation. The information about cell mates can still be obtained by performing an equi-join of the Prisoners relation with itself, on the Wing and Cell attributes (with the added condition that the Prisoner ID's aren't equal).

Some clarifications:

1. The cell numbers repeat within each wing. Hence a combination of the cell number and wing number is necessary to locate a cell. This also means that neither cell number and nor the wing number is functionally dependent on the other.
2. The security level of a prisoner is his individual characteristic, which is to guide the prison staff as to how careful to be around that prisoner. It is neither functionally dependent on the cell nor on the cellmate of the prisoner, as prisoners with different security levels can be cell mates.



The Final Relational Model

Examples

PRISONERS

Prisoner ID, First Name, Middle Name, Last Name, Sex, DOB, Height, Weight, Blood Group, Medical History, Arrival date, Sentence, Security Level

2018101071, Michael, Jackson, Ross, Male, 21 October 1989, 5'5", 71, B+, None, 12 November 2018, 2 years, Low, C19, W4

2014101092, Frank, Marko, Gallo, Male, 19 August 1974, 6'1", 88, O+, Asthma and Mental illness, 13 February 2014, 10 years, High, C19, W4

2015101011, Pearson, Specter, Litt, Female, 03 June 1965, 5'8", 65, AB-, None, 07 July 2016, 5 years, High, A11, W7

CRIMES

Prisoner ID, Crime

2018101071, Burglary

2018101071, Sexual Assault

2014101092, Smuggling

2015101011, Murder

OFFENCES

Offence ID, Description, Location, Date-Time, Severity

OF1018, Prison Escape attempt, GF Washroom 12, 26 Oct 2019 - 11:03 am, Low

OF0016, Physical fight between 2 gangs - multiple inmates hospitalized due to excessive bleeding, 21 Aug 2018 - 9:44 pm, High

OFFENCE TYPE

Offence ID, Type

OF1018, Attempted escape

OF0016, Destruction to property

OF0016, Insubordination

OF0016, Assault

JOBS

Job ID, Job Name, Working hours, Supervisor ID

JB101, Laundry, 09:00 - 11:00, PS021

JB003, Kitchen, 06:00 - 08:00, PS031
JB005, Groundskeeping, 19:00-21:00, PS001

PRISON STAFF

Staff ID, First Name, Middle Name, Last Name, Sex, DOB, Address, Phone, Post, Salary

PS001, Pranav, Pramod, Kirsur, Male, 11 Sept 1988, B83 Kala Marg Hyderabad, 9899871125, Prison Officer , 100000 pm
PS006, Jivitesh, NULL, Jain, Male, 11 Dec 1974, J18 Jackson Enclave Hyderabad, 9116677290, Visiting Psychologist, 70000 pm
PS009, Shradha, Malik, Sehgal, Female, 21 Oct 1977, A4 120 Gachibowli Hyderabad, 9781134340, Guard, 30000 pm
PS011, Naman, Kumar, Sehgal, Male, 02 Dec 1975, F4 10 Jubilee Hills Hyderabad, 9780138360, Guard, 30000 pm
PS013, Bhavya, NULL, Sharma, Male, 15 Dec 1978, E19 Gachibowli Hills Hyderabad, 9899116633, Prison Officer, 30000 pm
PS031, Namani, Kumari, Sootha, Female, 02 Dec 1965, F 10 Banjara Hills Hyderabad, 7781138360, Cook, 30000 pm
PS021, Jyoti, NULL, Lanka, Male, 12 Dec 1985, F4 10 Konda Hills Hyderabad, 8880138370, Laundry head, 30000 pm

GUARDS

Staff ID, Shift, Wing, Supervisor ID

PS009, 06:00 - 18:00, W4, PS013
PS011, 20:00 - 08:00, W7, PS013
PS013, 00:00 - 15:00, W6, PS001

APPEALS

Appeal ID, Filing date, Hearing Date, Status, Prisoner ID

AP106, 11 Nov 2018, 21 Feb 2019, Closed, 2018101071
AP003, 12 June 2019, 28 Nov 2019, In review, 2014101092

VISITORS

Prisoner ID, First Name, Middle Name, Last Name (of visitor), Relationship, Address, Phone

2018101071, Nishant, NULL, Thakur, Father, D18 Kala Kunj Hyderabad, 9077188890

2014101092, Deeksha, Surya, Anand, Sister, 221B Baker Street Hyderabad,
8822610109

EMERGENCY CONTACTS

**Prisoner ID, First Name, Middle Name, Last Name (of emergency contact),
Relationship, Address, Phone**

2014101092, Akshaan, Mathur ,Kumar, Father, 21B Kondapur Hyderabad,
7046155592

2018101071, Aishani, Rachna, Saha, Mother, P33 Sarvodaya Enclave New Delhi,
9889911256

CRIMES

Prisoner ID, Crime

2014101092, Assault

2015101011, Homicide

2015101011, Felony

INCIDENT PRISONERS

Offence ID, Prisoner ID

OF1018, 2018101071

OF0016, 2018101071

OF0016, 2014101092

INCIDENT GUARDS

Offence ID, Guard ID

OF0016, PS009

OF0016, PS011

As you can see, no guard associated with the offence OF1018

*Thus, two cross reference tables are necessary as the primary key would have been
NULL in case of one table*

VISITS

Prisoner ID, First Name, Middle Name, Last Name (of Visitor), Guard ID, Date-Time

2018101071, Nishant, NULL, Thakur, PS009, 2 Dec 2018 14:00

2014101092, Deeksha, Surya, Anand, PS009, 31 Oct 2018 19:00

ASSIGNMENT PRISONERS

Job ID, Prisoner ID

JB101, 2018101071
JB003, 2018101071
JB003, 2014101092
JB005, 2015101011
JB005, 2018101092

ASSIGNMENT GUARDS

Offence ID, Guard ID

JB101, PS009
JB003, PS009
JB003, PS013
JB005, PS013

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